The Journal of the Indian Botanical Society

Vol. XXXVII 1958 No. 1

SOME ASPECTS OF INDIAN HEPATICOLOGY*

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Introduction

As I rise to face you from this tribune, I am deeply moved to feel your overwhelming kindness and goodwill to one whose greatest privilege it is to have been linked with you for more than three decades and a half; almost ever since the inception of this Society. The honour you have done me is, indeed, the highest that members of any such academic association can confer on one of their colleagues. It fills me with pride and gratitude as it also gives me an intense feeling of humility and a sincere desire to be worthy of the confidence you have reposed in me.

Turning now to the theme of my address on this occasion I may confess at the very outset that there is an inherent tendency among specialists to attach too much importance to the branch in which they happen to be especially interested and as L. M. Underwood (1894), in a learned address before Section G of the American Association for the Advancement of Sciences at its Borooklyn Meeting had aptly remarked, 'We are all more or less inclined to ride our own hobbies in public places.....' I too do not wish to deviate from this time-honoured tradition, as I think, in one way, it is also better, since in so doing I shall at least be treading the path which has been followed by many of my distinguished predecessors and which I am sure will also be pursued by most others who are yet to come.

However, without any intentions, at any rate, to over-estimate the importance of the group of plants which has interested me for the past few years it is my desire to crave your indulgence for a little while as I lay before you, some aspects of this somewhat obscure group of Indian Cryptogams—the Hepatics.

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* Presidential address delivered at the Annual Meeting of the Indian Botanical Society, Madras, January, 1958.

I. Teaching of Liverworts in our Universities and a Suggestion in this Direction

I hope I will not be misunderstood neither will it be considered presumptuous on my part if I venture to make some suggestions in connnection with the teaching of hepatics at the level of the Bachelors' courses in our universities. The ideas put forth by me have been arrived at as a result of my own leanings towards the study of these plants as well as from my experience as one entrusted with the teaching of this group in one of our universities.

The hepaticæ have attained complexity of structure along three distinct lines. The Marchantiales show the highest degree of internal differentiation of the gametophyte, the Acrogynæ (the leafy liverworts) display the most varied structure in the external form of the same generation while the Anthocerotales exhibit the maximum differentiation of the sporophyte. Yet, as L. M. Underwood (1894) observed, at about the close of the last century, even at the present time, " The hepatics among us are popularly supposed to be thallose or thalloid plants and *Marchantia* is regarded as a normal representative. As opposed to this widespread misconception, it should be noted that as far back as the date of the last publication of a general synopsis of the Hepaticæ (1847) the relative numerical importance of the Marchantiaceæ was only 17 per cent. of the entire group and the increase since that time has been even more largely in the direction of the other groups, especially the foliaceous Jungermanniaceæ ".

To-day, as our knowledge of liverworts has further advanced, the relative percentage of the leafy members of the group has risen still higher and, according to the details given by Fulford (1947), they comprise more than 85% of the total 8,500 species and include 180 genera and 7,200 species as against 62 genera and 1,290 species distributed among the remaining groups.

Besides, as Fulford (*l. c.*) writes elsewhere, " The leafy liverworts, because of their relatively simple structure and relatively smaller number of cells involved, show great promise as material for fundamental researches ".

It is, therefore, to be regretted that the representation of this tripartite group in the syllabi of most of the Indian universities, at the stage of the Degree courses, is often confined to one or two thalloid genera, *e.g.*, *Riccia* and/or *Marchantia*, at times supplemented by *Anthoceros*. In a few cases *Pellia* is also included while in exceptional cases *Madotheca*, a member of the leafy liverworts, may be an additional type for the purpose.

Such an inadequate and disproportionate representation of the liverworts in the teaching curricula of our universities, coupled with the paucity of suitable accounts of the representative members of the different sections of this group of Cryptogams from the literature on Indian Bryology, has resulted in a very imperfect knowledge and even erroneous

comprehension of the liverworts among our students and in the words of L. M. Underwood (*l. c.*) "The group....has suffered at the hands of general botanists and through them an incomplete and one-sided conception is transmitted to the generation of botanical students now coming to maturity..... Armed, however, with such a conception.... the student goes forth into the field to study liverworts and after he has exhausted *Marchantia* and *Conocephalus* and has possibly seen a *Riccia*, he is usually stranded and knows not what to seek..... The Lophocoleas, the Cephalozias, the Frullanias and the Radulas, so elegant in their structure as to impress the least æsthetic student with their beauty, so diversified in their evolution as to demand the exercise of his most active powers of reflection, and withal so simple in their structure as to render them accessible with a minimum of microscopic technique—these are a closed volume to him because of the limitations of his early instructions and impressions".

I would, therefore, earnestly appeal for a more effective representation of the liverworts in the syllabi of our universities and for a more judicious selection of the types from each one of the major groups.

The Marchantiales with *Riccia* and *Marchantia*, as is usually adapted by several of our universities, are fairly well represented, so are also the Anthocerotales with the inclusion of *Anthoceros* (Linn.) Prosk. or *Phæoceros* Prosk. The Jungermanniales, with their two major groups, have mostly escaped our attention and I feel one type, either *Pellia* or *Riccardia* from the Anacrogynæ or the Metzgerinæ and two members, *i.e.*, *Madotheca* and *Frullania* from among the Acrogyanæ or the foliose liverworts would serve the minimum required to impart the basic knowledge of these plants.

While making these suggestions I feel confident that but with a little orientation and adjustment these can be easily incorporated.

The types suggested are more or less among those liverworts that have received comparatively greater attention from the morphologists so that suitable published accounts of the morphological details of these genera will easily be available. Besides, all these liverworts are quite common in our flora and can be collected without much difficulty in suitable condition for class work.

II. Liverworts in Indian Herbaria and Our Floras of these Plants

The building up of suitable collections of liverworts in our Herbaria and the preparation of local and State floras of Hepatics, the two interconnected problems of fundamental importance to Indian Hepaticology, have apparently received very little attention from the botanists of our country. It is well recognised that the study of any branch of Systematic Botany is always handicapped and incomplete without these and we look forward to the newly organised Botanical Survey of India to shoulder this responsibility. However, the various universities and the State and the National Botanic Gardens in the country should also

lend their helping hand in the achievement of these objectives as, in a vast country like ours, these are formidable tasks and need constant efforts and attention of all competent to carry them out.

The role of the universities, in this connection, needs no emphasis as it must be admitted that without a good collection of plants the study of any branch of Botany is always handicapped and incomplete. There is yet another reason for my approach to the universities in this case.

As W. C. Steere (1940) puts it "....in spite of their beautiful symmetry and delicate structure liverworts have been neglected by both amateur and professional botanists....", a statement which is further corroborated from an examination of the data available on the morphological studies of this group.

"On an examination of the morphological studies that have been made, particularly those having to do with the life-history of a species," remarks Margaret Fulford (1948, p. 169), "one finds that investigations have been made on all the genera of the Anthocerotales (but not all the species); on perhaps 30% of the genera of both the Marchantiales and the Anacrogynæ and perhaps 5% of the genera of the Acrogynæ. One does not have to point out that there is still very much information to be gained through investigations of the living hepatic flora. It has been and is still a much neglected group of plants".

A couple of years ago Rev. H. Santapau (1956), in his learned Presidential Address before the Society, while advocating the need for the compilation of floras of the country observed, "When speaking of Systematic Botany I do not mean to confine myself to Angiosperms. We need national and provincial floras of the Algæ, Lichens, Bryophytes, etc., of the country; of late such plants have assumed great economic importance and if our students wish to help in the development of natural resources of India, they need proper floras to cover such aspects of the vegetation. It is to be regretted that sufficient work has not been done on so many of the lower groups; but if at least we have proper floras to give in concise form whatever has been known about such plants more students might feel inclined to go for them in the field."

A perusal of the literature published on Indian Hepatics, reference to which is available in the reviews published on the subject from time to time (Pandé, 1936; Pandé and Bharadwaj, 1952; Pandé and Srivastava, 1957; and Pandé, in Hundred Years of Bryology in India, MS) would show that there is a general lack of suitable floras dealing with the liverworts of different territories and also of the country, as a whole; the only contribution in recent times on the subject is a publication by the late Prof. Kashyap (1929; 1932) on the Liverworts of the Western Himalayas and the Punjab Plain. It is, therefore, necessary that these plants from different territories are intensively collected, studied and local and State floras are made available to students.

It may also be pointed out here that such a task for this group of plants has been rendered somewhat more difficult as most of the early collections by such eminent persons as Wallich, Weight, Hooker, Griffith, Duthie and many others, on which publications pertaining to Indian Hepatics, in the last century, by Griffith (1849; 1849 *a*), Gottsche, Lindenberg et Nees (1844), Mitten (1860–61), Stephani (1900–24) and others are based, have not been maintained and preserved, as far as I am aware, anywhere in the country, except for some of the collections of the West Himalayan Liverworts, located in the Herbarium of the Forest Research Institute, Dehra Dun. All our early collection of hepatics, which include the types of most of our Indian species of this group, have gone out of this country and often it is difficult, if not altogether impossible, to get authentic specimens even for comparison.

Besides, as most of our early collections of liverworts were made by those who, though sometimes scholars and scientists of great repute and attainments, including some of the distinguished botanists in some other branch of the subject, had little use for liverworts and, also as there has been an inherent desire, and public and official pressure, to amass things of economic value and something really magnificent, it is but natural that the liverworts are only poorly represented in their collections. Nevertheless, we must acknowledge our deep sense of gratitude for the benefit rendered to Indian Hepaticology through the disinterested labours of these indefatigable and accomplished collectors of the last century from distant lands, to some of whom at least, botany was more of a pastime than a profession.

In recent years, the late Prof. Shiva Ram Kashyap, to whose contribution I referred a few minutes before, made valuable collections of these plants. He was one of the pioneers and seniormost of Indian Botanists of repute, a person of profound grace, intense religious faith and a truly great figure, who must always remain illustrious in the annals of botanical science. His first contribution, which is also perhaps the first, ever written on Indian liverworts by one of our own countrymen, in 1914, marks the dawn of a new era in the History of Indian Hepaticology. Through his ceaseless efforts and unfailing encouragement Kashyap created a school of Indian Hepaticology and through his own critical studies placed on high pedestal a new concept of the Phylogeny of the Liverworts (Kashyap, 1919) advanced by Goebel (1910) only a few years earlier. Possessed by an inherent zeal, characteristic of a naturalist, coupled with an intense desire to know more and more of the unknown regions of the Himalayas, Kashyap repeatedly strived hard to explore the celestial height of these glorious mountain ranges from Kashmir on the West to Darjeeling on the East. In each one of his sojourns he succeeded in gathering numerous Himalayan and Tibetan plants of unusual interest and rare beauty, including specimens of many uncommon and new liverworts, which he deposited at the Government College, Lahore, and created the nucleus which gradually grew, in his own lifetime, into a fair Herbarium of these plants. There are few to whom opportunities come and fewer still who having got them, utilise

them to the best extent. Kashyap belonged to the latter category of persons. The rich treasure of liverworts which he amassed at Lahore will bear testimony to the above and go down to posterity as a notable example of the efforts of an individual of firm determination, indomitable will and profound faith in God and full confidence in himself. It is to these sterling qualities of this great man, the Father of Indian Bryology, more than anything else, that I pay homage and earnestly desire all devoted to this branch of Indian Botany to aspire for. The high pedestal which Indian Hepaticology attained through the researches of the late Prof. Kashyap may not perhaps be possible for each one of us to raise higher. In fact it is only few who are endowed with such a rare talent. But we can all contribute our share towards the establishment of a decent collection of these plants and thus provide material for the building up of the edifice, the flora, which is so essential for the progress of any branch of systematic botany in any country.

For this reason I earnestly feel that to achieve any success in this direction, we need wholehearted co-operation and full sympathies of all interested in these plants; the members of the Botanical Survey of India, including the Chief and the Regional Botanists, the Directors, and Staff of the States and National Botanic Gardens and above all a suitable personnel competent and fully qualified to study and look after these plants in the various zones of the Botanical Survey of India and, if possible, also in other similar departments and gardens. It is my earnest hope that this appeal of mine from this platform would receive due consideration and support from all concerned.

Collections Available for Study

Nearly 35 years ago a remark from my *Guru*, the late Prof. Kashyap, that I should make my own collections instead of writing to him for material, although came as a shock at that time, provided me with the impetus that I have to earnestly devote myself for the furtherance of the study of hepatics. I realised that the task was rather difficult but nevertheless fascinating and full of promise as it would provide not only a rare opportunity to see new and interesting plants as they grow and develop in nature but also to advance, if possible, the study of Indian hepatics which by that time had not gone much beyond the infant stage. The extensive and vast territories with luxuriant growth of liverworts were nearly a closed chapter till then. Struck by this idea I started with a missionary zeal to put in my best with a view to study, if possible, some aspects of this interesting flora and during these few years it has been my sincere endeavour to assemble data on the hepatic vegetation of India. This has naturally involved undertaking long and arduous journeys on foot in quest of material from nearly all parts of the country and I have great satisfaction that collections are now represented in our herbarium from nearly all the various geographical units of the country. A representative collection of Indian hepatics has thus gradually emerged and is now available for investigation.

Apart from numerous excursions taken from time to time to several of the neighbouring hill stations in the Western Himalayas it has also been possible to organize long tours on foot reaching almost to the line of the perpetual snows in the Western as well as the Eastern Himalayas. Collections have also been made from other parts of the country. Tnese are listed below:—

TABLE I

1. *West Himalayan Territory*

(*a*) 1936. Pindari glaciers—*ca*, 12,000 ft. Almora to Pindari glaciers—the source of the Pindar Ganga—trekking a distance of about 75 miles, on foot, each way.
(*b*) 1937. Milam glaciers—*ca*, 13,000 ft. Almora to Milam glaciers—near Unta Dhura Pass—the source of the river Gauri—travelling a distance of about 90 miles, each way on foot.
(*c*) 1938. Gaumukh. Mussoorie to Gaumukh, *ca*, 12,000 ft.—trekking a distance of about 100 miles each way.
(*d*) 1943. Jamnotri track—*ca*, 9,000 ft.—the source of the Jamuna. Mussoorie to Jamnotri, trekking on foot in the Jamuna Valley through a distance of about 80 miles, each way.

2. *East Himalayan Territory*

(*a*) 1941. Darjeeling—Sandakpu in the region of the Sikkim Himalayas—a circular tour travelling a distance of over 200 miles varying in altitude from 4,000 ft. to 12,000 ft.
(*b*) 1952. Khasi—Jayanti hills in the Assam hills, making collections from Gauhati, Shillong, Mauflong virgin forest, Cherrapunji, Dawoki and other places in these hills ranging in altitude from 4,000 to 8,000 ft.

3. *Central India Zone Including the Gangetic Plain*

(*a*) 1945. Dwarka.
(*b*) 1951. Pachmarhi. 5,600 ft.
District of Lucknow and its neighbourhood.

4. *Eastern Coast Region Including the Nilgiris and the Deccan Plateau*

1950. Nilgiris, Ootacamund, Dodabetta, 8,000 ft.; Coonoor, Coimbatore, etc.

5. *Western Ghats*

1950. Mangalore, Someshwar, Agumbe, Jog Falls, Shimoga.
1951. Mercara.

6. *Ceylon*

1939. Colombo, Galle, Kandy, Pedro's Peak, Hakgala, Nuwara Eliya, etc.

In this connection I deem it my great privilege to acknowledge here the kind facilities and active help I have received both from the late Prof. B. Sahni and Prof. S. N. Das-Gupta. But for their keen interest and unfailing and continuous support it would not have been possible for me to gather these plants. In most of these tours Prof. Das-Gupta has not only been my companion and has borne with me the rough and tumble of the journeys in the difficult mountain tracks but has actually been my leader and collected some of the rarest specimens in my collections. Several of my colleagues and students have also been extremely helpful and have ungrudgingly contributed their shares, *viz.*, the late Mr. R. N. Misra, Dr. D. C. Bharadwaj, Mr. Ram Udar, Mr. S. Ahmad and Dr. K. P. Srivastava and several batches of the M.Sc. students of the University of Lucknow.

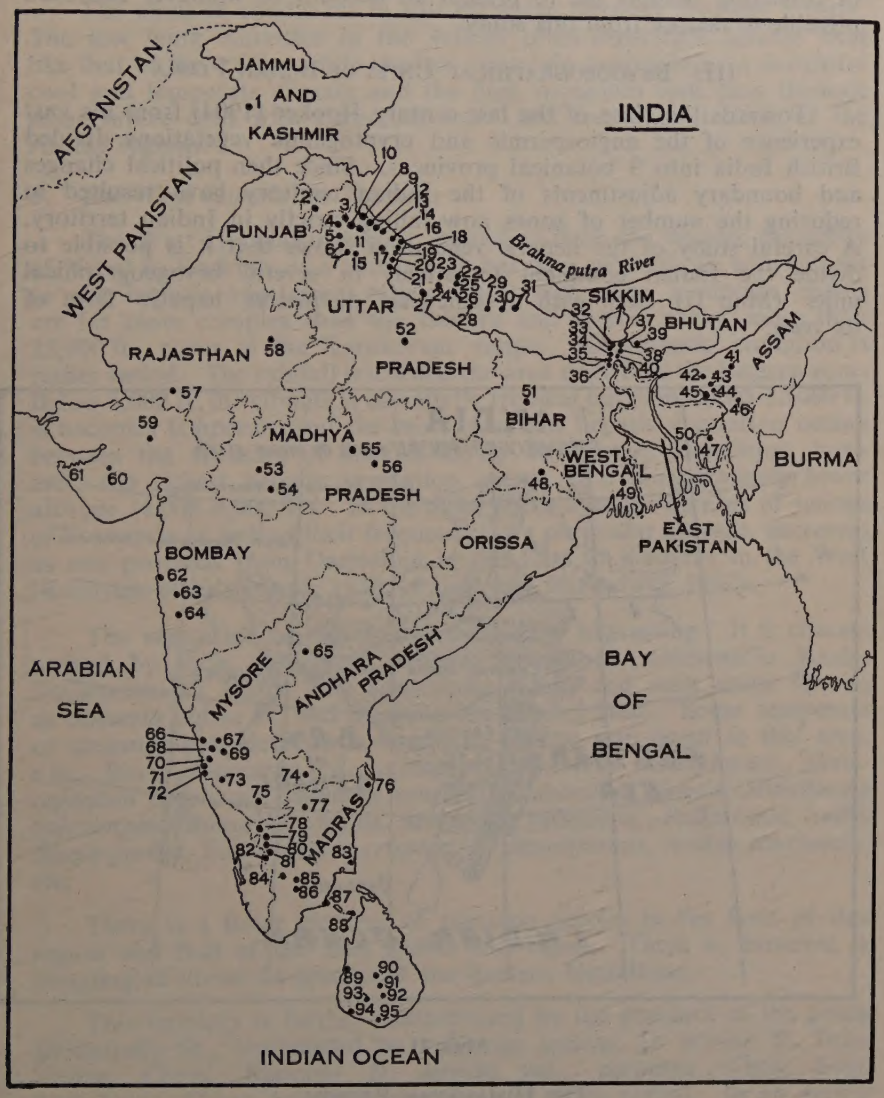
It reminds me especially of the late Mr. R. N. Misra whose zeal, both as a collector and researcher, can only be appreciated by those who have seen him work in the field and in the laboratory. Unfortunately this active young man was removed from our midst before he could get any opportunity for the display of the talent he possessed.

It would thus appear from Table I and Map I that collections have been made from the lofty Himalayas in the North, both from the Eastern as well as Western flanks, Assam, Central India, South India and Ceylon. I must frankly admit, however, that these collections have largely been made mostly only at one particular season and are primarily roadside collections. A rich fruitful crop in the interior, therefore, awaits discovery at the hands of some young and enthusiastic bryologists. Judging from the vast Indian territory much area still has been left uncovered and much of the flora remains to be worked out.

These collections have been further supplemented by some other excellent collections of Indian hepatics, *e.g.*, extensive collections of the East Himalayan hepatics by Decoly and Schaul (Sikkim-Himalaya, 1898–99), valuable plants from the famous herbarium of E. Leveir, which include authentic specimens identified and established by such renowned hepaticologists as V. Schiffner and Stephani and also many new and un-named species; South Indian hepatics collected by I. Pfleiderer of Esslingen (Germany) and identified by Stephani; valuable collections from the Nilgiris by Father Foreau, a collection from Spiti (10–11,000 ft.) by Dr. M. N. Bose, and also several other collections from other parts of the country sent by numerous friends.

Recently collections of Hepatics from Nepal, under the ægis of the British Natural History Museum, by Stainton, Sykes, Williams and Polunin have been placed in my hands for identification (*see* Pandé and Udar, 1957). Besides these my collection also includes valuable specimens from the territory of Bhootan and Sikkim, Japan, Siam (1899–1905), Ceylon (1898), Sumatra (*ca.* 1878) received through the kindness of the late Prof. V. Schiffner along with part collections from Java, Europe, America and Africa, kindly sent to me recently by Dr. W. Meijer, Dr. Margaret Fulford, Dr. McGregor, Dr. C. E. B.

Bonner, Prof. A. C. Coundwell, Dr. E. W. Jones, Dr. T. C. Frye, Dr. S. Hattori and others. All this is proving extremely helpful in our investigations.



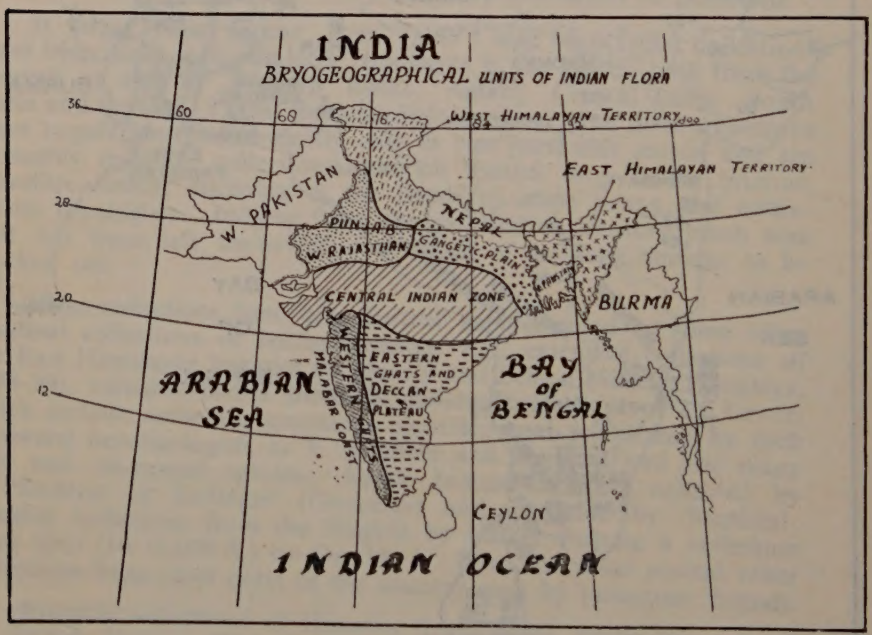
MAP I

From an examination of these collections and also the notes prepared on the spots and the sketches and photographs that have accumulated during these collection trips it has been possible to reach some

tentative conclusions with respect to the interesting distribution patterns of some of our hepatics and although I do not lay any claim to be a plant geographer yet the experience gained during the last several years of collecting tempts me to present an account of whatever has been possible to deduce from this study.

III. Bryogeographical Units of Indian Flora

Towards the close of the last century Hooker (1904) from his vast experience of the angiospermic and cryptogamic vegetations divided British India into 9 botanical provinces. Since then political changes and boundary adjustments of the Indian territory have resulted in reducing the number of zones now falling strictly in Indian territory. A careful study of the hepatic vegetation shows that it is possible to divide the Indian continent tentatively in several bryogeographical units (Map II) each with a somewhat distinctive hepatic flora of its own.



Map II

The Himalayan Region

The lofty Himalayas occupy a unique position in the Geography of the world and have been and still are the most fascinating area both for the tourists as well as the botanists. Extending for more than 1,500 miles with an average width of 150 miles, these lofty mountain ranges on the northern frontier of India form a link between the

Mediterranean countries and Eastern Asia where there is a remarkable mingling of plants belonging to Eastern and Central Asia, the Indo-Malayan region, and the Tropical South and S. East regions.

The climatic conditions in this extensive territory are very diverse. The low lying countries in the valleys often experience intense heat like that of the tropics while the low mountain ranges enjoy a delightful cool and temperate climate and the high mountain tops pass through most severe cold with perpetual snow and ice, characteristic of the Alpine regions.

1. *The West Himalayan Territory*

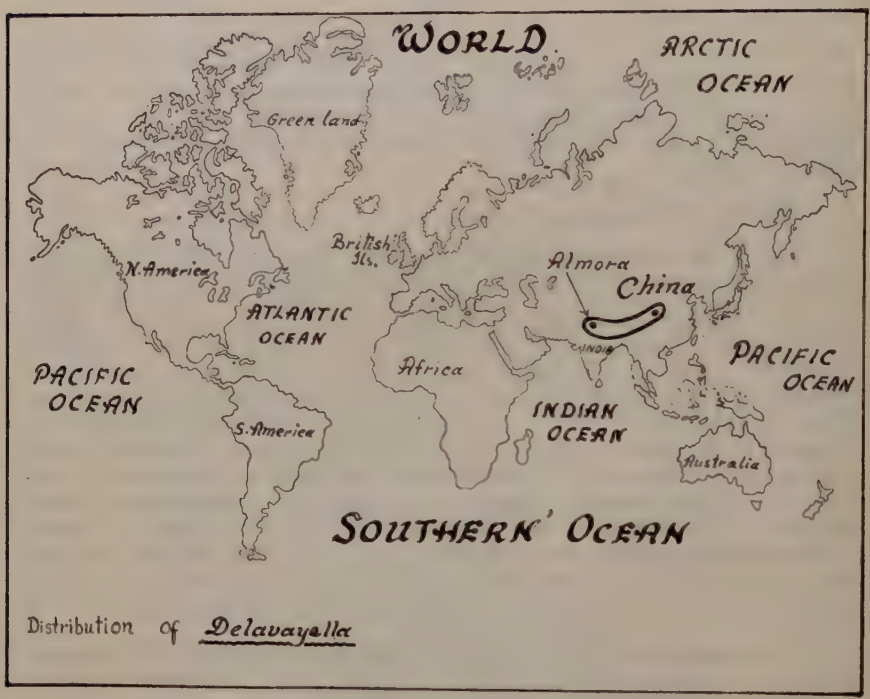
The West Himalayan region, extending from the western boundary of Nepal to Kashmir, is a zone which has been worked out with respect to the hepatic vegetation rather intensively. The mountain chains are far more complex than the Eastern and several peaks, more than 25,000 ft., occur in the Karakoram range. The climatic condition is rather varied. The rainfall is less and the area drier than the Eastern zone. Below 5,000 ft. the climate is essentially tropical but from 5,000–12,000 ft. it becomes temperate and the most luxuriant hepatic vegetation occurs between the altitudes of 6,000–8,000 ft. In Eastern Himalayas, however, the richest hepatic vegetation occurs at a comparatively lower altitude (4,000–6,000 ft.). In the outer Himalayas the number of species of liverworts as well as their frequency, at a particular altitude, decreases as one proceeds from Darjeeling in the East to Kashmir in the West (Kashyap, 1929; Pandé, 1936; Pandé and Bharadwaj, 1952).

The vegetation of this area is sufficiently interesting. It is characterized by such monotypic endemic genera as *Aithisoniella* Kash., *Stephensoniella* Kash. and *Sewardiella* Kash. and such arctic species as *Sauteria alpina* N. and *S. spongiosa* (Kash.) Hatt. Some temperate or cosmopolitan elements common to Europe also occur in this area, *e.g.*, *Riccia sorocarpa*, *R. crystallina*, *Reboulia hemispherica*, *Conocephalum concicum*, *Lunularia cruciata*, *Dumortiera hirsuta*, *Marchantia polymorpha*, *Riccardia pinguis*, *Metzgeria pubescens*, *Pallavicinia lyellii*, *Blasia pusilla*, *Fossombronia crispata*, *F. cæspitiformis*, *Acolea concinnata*, etc.

There is a lesser element of common species in the flora of this region and that of the East Indies and Japan. There is, however, a mingling of about 34 species of the Eastern Himalayas.

This territory is further characterized by the presence of the genus *Delavayella* St., represented by only one species, *D. serrata* St. from Yunan, China. Recently *D. serrata* var. *purpurea* Chen, from Szetschwan, China, has been described by Chen (1955). In an earlier communication Pandé and Srivastava (1942) described a new species, *Nowellia indica* Pandé et Srivastava, based on a collection from near Girgaon (6,000 ft.), about 67 miles North-East of Almora, in the Western Himalayas. This plant is absolutely identical with *D. serrata* var. *purpurea* Chen. Yet another species, *Nowellia orientalis* Chopra,

known from sterile specimens from Darjeeling (Chopra, 1938), is also the same. (Map III).



MAP III

An interesting plant, *Anthoceros gemmulosus* (Hatt.) Pandé *comb. nov.* was collected above Munsyari during the Melam tour (Plate I, Fig. 1) and an elegant *Frullania* forming well-defined rosettes and growing copiously on rocks between Someshwar and Bageshwar was also collected. (Plate I, Fig. 2).

2. *The East Himalayan Territory*

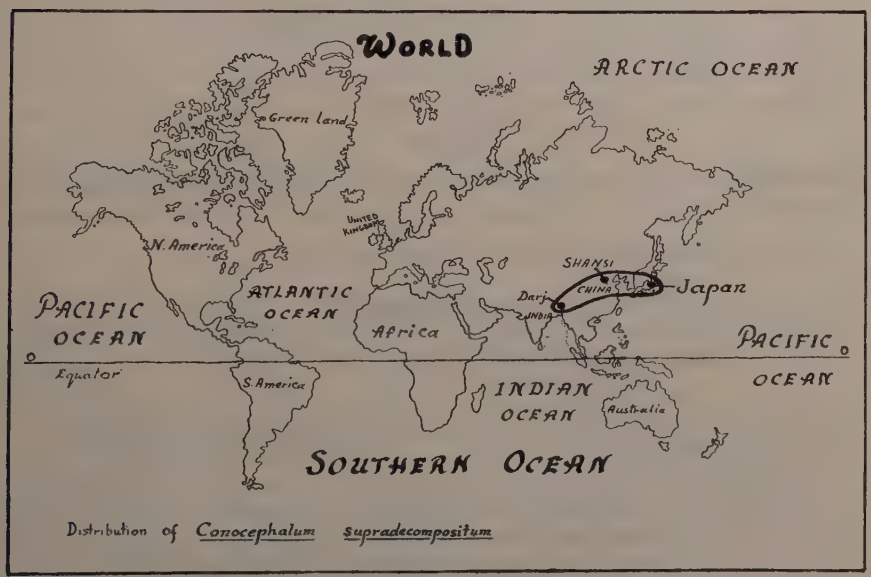
The Eastern Hill region comprises the Eastern parts of the mountains of the Indian territory, the hills which separate India proper from Burma and China and which occupy a considerable portion of Assam. The majority of the peaks average 6,000–10,000 ft. and some peaks rise upto 25,000 ft. The region as a whole receives the main Bengal current of the monsoon and the rainfall is very heavy.

The Assam Plateau facing directly the path of the monsoon receives torrential downpours and Cherrapunji receives nearly 500 inches a year while over the surface of the plateau the rainfall decreases and Shillong receives only 83 inches.

The very humid climate induces an abundant growth of mosses and liverworts and the Eastern Himalayas apparently represent the richest liverwort territory in India with about 338 species recorded so far. This number, however, is at best tentative as further search in this congenial habitat ot liverworts, is likely to bring to light many more species.

The flora of this territory is a remarkable mingling of the species of Japan, China and Indo-Malayan region and is characterized by some extremely rare and interesting plants curiously confined only to these territories. Some of these are discussed below:—

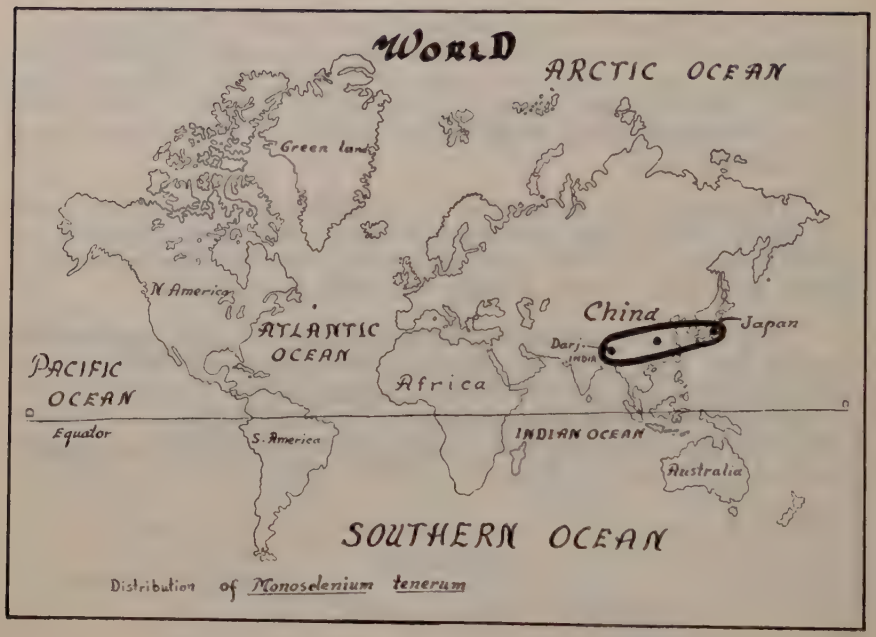
Conocephalum supradecompositum (Lindb.) St. is a rare species having been reported so far from the subtropical regions of Japan and the Province of Shensi from China (Stephani, 1900) and now reported a few years back from Darjeeling in the Eastern Himalayas on the basis of a collection made by Professor P. Maheshwari in 1941 and kindly sent to me (Pandé and Bharadwaj, 1949). (Map IV).



MAP IV

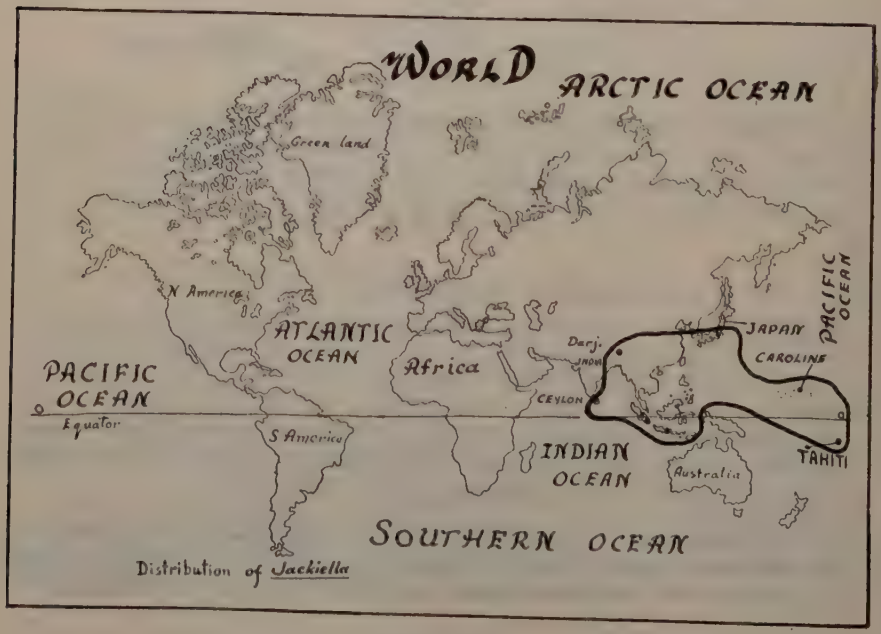
Monoselenium tenerum Griff., initially described from Assam (Griffith, 1849) has since been discovered in China (Goebel, 1910; Chen, 1956) and Japan (Hattori, 1951). (Map V).

Jackiella Schffn. represented by only 5 species, is distributed in Japan, Java, Ceylon, Sumatra, Singapore, Tahiti, and Caroline Islands. *J. javanica* var. *carvifolia* Schffn. is one of the most valuable hepatics



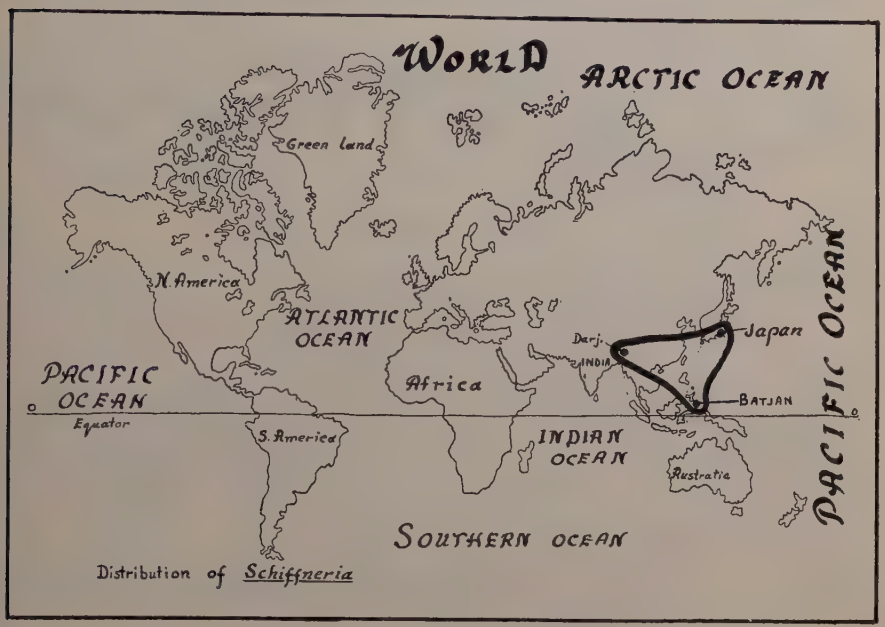
MAP V

represented in the collection of Decoly and Schaul from Darjeeling. (Map VI).



MAP VI

Schiffneria St., represented so far by two species, *S. viridis* St. from Japan and *S. hyalina* St. from Batjan, is also represented in our flora by *S. levieri* Schffn. from Darjeeling. (Map VII).



Map VII

Megaceros stahlii is yet another interesting plant with a highly restricted distribution in Java and Darjeeling. In India this plant has been reported for the first time by Schiffner and Pandé (1950). (Map VIII).

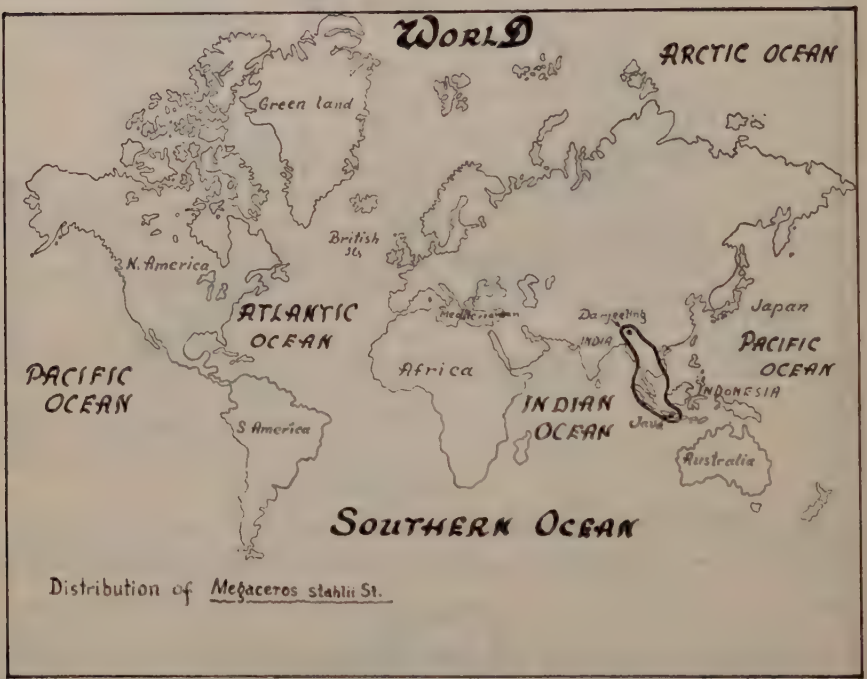
The distribution pattern of these plants is sufficiently interesting. (Maps II–VIII). What could be the cause of such restricted distribution? May be in past there was a more widespread distribution and with the changes due to land migrations and variations in the climate and topography, these plants have persisted only in restricted favourable areas and have perished and disappeared from others.

The Punjab and the West Rajasthan Plains

This area lies in a region of very low and irregular rainfall and most unsuited for hepatic growth. The Punjab plains, particularly the North-Eastern and the South-Eastern plains are the wettest part and receive on an average 20–30 inches of rainfall. This area has been covered by Kashyap (1929, 1932) in the excellent contributions made by him.

Proceeding southwards of this territory the vegetation gradually diminishes due to very low rainfall and aridity and in the Indian deserts

there is hardly any possibility of the growth of these plants. However, such xeromorphic species as *Plagiochasma appendiculatum*, *P. articulatum*, *Asterella angusta*, *A. pathankotensis*, *Targionia hypophylla* and some species of *Riccia* have been gathered from this part during the favourable season.



MAP VIII

CENTRAL INDIA AND THE GANGETIC PLAIN

The hepatic vegetation of this area is not yet fully known. Only two isolated plateaus have received some attention—Mt. Abu, the highest peak in the S-W. end of the main Aravalli range, and its neighbourhood (Chavan and Mahabalé, 1945; Pandé and Udar, 1957) and Pachmarhi, a summer hill station of Madhya Pradesh (Pandé and Srivastava, 1952). The average annual rainfall, though not high in these areas, averages 70–80 inches and in favourably sheltered spots the hepatic vegetation is sufficiently luxuriant. About 40 species of hepatics, distributed over 26 genera, are represented in these territories. Of these 26 are common to the Western Himalayas, 18 to Eastern Himalayas and 24 to S. India and a species of *Cephalozia*, *C. herzogiana* Pandé *et* Srivastava (Pandé and Srivastava, 1955) and a species of *Riccia*, *R. aravalliensis* Pandé *et* Udar (Pandé and Udar, 1957 *a*) are new to Science. In this region, therefore, there is an admixture of the

species from S. India and the Himalayas and this territory is a meeting ground for the hepatics of the North and the South. A more thorough search in this extensive territory is likely to yield some interesting forms.

From the Gangetic plain only Lucknow seems to have been thoroughly searched for hepatics and 15 species distributed over 6 genera occur here. Some very interesting plants have been collected from the Gangetic plains. A new species of *Riella*, *R. vishwanatha* Pandé *et al.*, from Varanasi (Pandé *et al.*, 1954), *Anthoceros crispulus* from the side of a lake in Mohanlalganj and *Riccia curtisii* from the same locality (Pandé and Ahmad, 1944). From these finds, it appears that future search is likely to reveal some more interesting plants.

Southern Zone

The flora of this large portion of India, bounded in the north by the Vindhyas and the Rajmahal hills and extending south to Cape Camorin, comprises two very distinct botanical provinces:

(1) *The West Coast Region* or the territory lying between the crests of the Western Ghats and the Arabian Sea comprises a narrow coastal plain and the slopes of the Western Ghats. The whole region is very wet and supports hepatic vegetation but the northern parts are comparatively dry. Towards the south the Malabar coast has shorter dry periods and relatively more humidity.

(2) *The East Coast Region* consisting of the Eastern Ghats, the Nilgiris and the Deccan Plateau.

(1) The West Coast Region

The hepatic vegetation of the West Coast is still imperfectly known and stands in need of thorough investigation. However, from the data available from investigations of Stephani (1900–24) and Chopra (1938) as well as from the examination of Pleiderer's collections as also my own, some interesting facts have emerged.

The hepatic vegetation in this area, particularly at Agumbe, Kuduremukh and Dodabetta, is extremely interesting. Agumbe, with the elevation *ca*, 2,600 ft. and a heavy annual precipitation of *ca*, 350″ in 1950 (when the plants were collected by me in this area), is ideally suited for the growth of numerous epiphyllous liverworts. These grow abundantly on trees, shrubs and even on herbs forming copious tangled mats on the leaves at times covering them completely. This collection still awaits a detailed investigation but even from a casual examination interesting facts have emerged which need emphasis. Several of the species of *Leptocolea*, *Cololejeunea*, *Diplasiolejeunea*, *Rectolejeunea*, *Microlejeunea*, etc., very strongly resemble their African allies, recently very ably described by Jones (1953 *a*, *b*; 1954 *a*, *b*; 1957). The differences at best appear to be very minor and it is highly likely that they are perfectly identical. It is further significant to note that the Mouflong forest in Assam and Raman, Rimbik and Jorpokhari in the Sikkim Himalayas also abound in many epiphyllous

liverworts which, curiously enough, approach to a very large extent the plants from S. India and Africa.

Particularly the distribution pattern of the genus *Leptocolea*, in this connection, is rather interesting. As earlier discussed by Pandé and Misra (1937), "many of the species are apparently of endemic nature and of restricted distribution; some obviously occupy larger areas, occurring often in two or more neighbouring territories but a few seem to be common to countries separated from each other by very long distances". In this connection *L. himalayensis* Pandé *et* Misra, *L. marginata* (L. *et* L.), Evans and *L. ocellata* Horikawa are very significant.

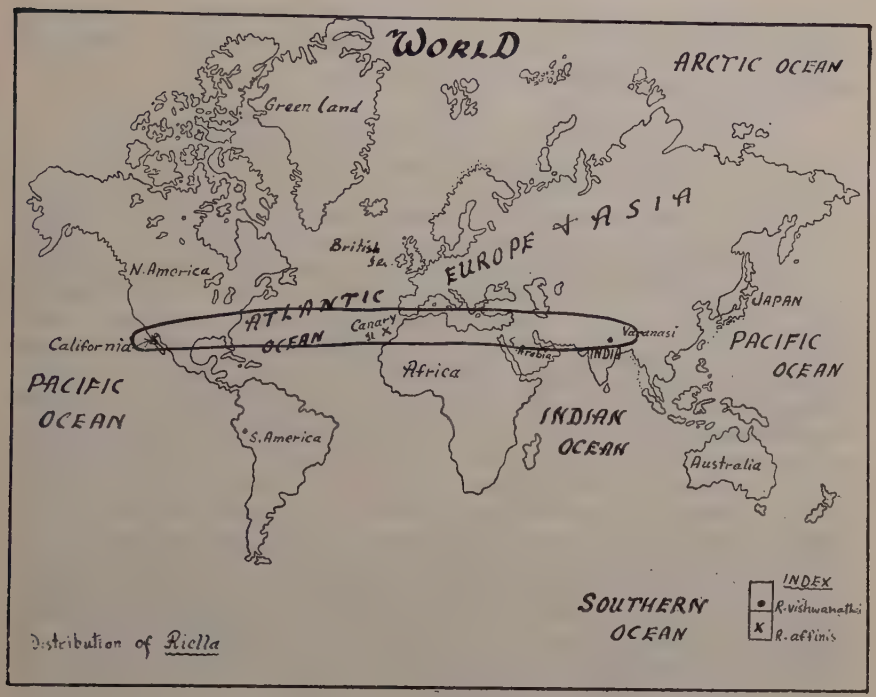
L. himalayensis, originally described by Pandé and Misra (1943) from the Western Himalayas has recently been reported from Africa by Jones (1957) and is also probably represented in S. India and Eastern Himalayas.

L. marginata and *L. ocellata* known from America and Japan were some time back reported by Chopra (1938) from S. India.

In this connection it is interesting to note that towards the close of the last century Schiffner (1899), from a study of the liverworts of Bhutan, pointed out the remarkable affinity of 15 species from this territory with that of Indian Archipelago noting that they may perhaps be identical. Such close affinities have been noticed in several of our species with their close allies in far off territories; one such case is that of *Riella vishwanathai* Pandé *et al.* from the Gangetic plains. This species has been recently pointed out by Proskauer (1955) to be identical with *R. affinis* known from California, N. America and Canary Islands in N. Africa. We had earlier noted the close similarity between these two species and since *Riella* is known to show abundant ecological variations the two may possibly be the same. The distribution pattern, as evident from the Map IX, is rather interesting.

Such a disjunct distribution, in now widely separated areas, is rather striking. What could be the cause of such a curious distribution? The spores of these plants have no special adaptability for wide dispersal and the areas are so widely separated by mountain barriers and large oceans that any possibility of their dispersal through them is rather inconceivable.

It is quite possible, however, that these plants had a much wider distribution in the past and due to isolation of land masses, changed topography, ecological segregation or some such overland migration routes now no longer present, the continuity of the vegetation was lost and these plants were subjected to diverse changes. Those with wide adaptability and possibly congenial microhabitats survived in their present homes and disappeared from others due to rigors of unfavourable changes and perished. Possibly also they underwent enough transformations and resulted in the evolution of new species.



Map IX

Besides, this area shows some 15 species common to East Africa and there is a great likelihood of the discovery of many more common species between these two territories. The Indo-African land connections were unbroken till cretaceous and perhaps these plants are thus remnants of a flora widespread before the separation of these two land masses.

I strongly feel that instances of distribution patterns of liverworts which I have presented before you from the study of hepatic vegetation of India, which can doubtless be multiplied, strongly favour Wegener's hypothesis of the Continental drift which has been ably supported by Prof. Sahni (1936) on palæobotanical evidence and by several others along with Fulford (1951) and Hattori (1951) from a study of the hepatic vegetation in their respective countries.

The East Coast Region and Deccan Plateau

This area too has so far not been extensively worked out. However, from the data available the Eastern Coast region has about 31 species common to Indo-malayan countries including Java, Formosa, Sumatra, Philippines, Luzon, Borneo, Siam, Carolina Islands, Nicobar, etc.

The Deccan Plateau has no distinctive flora of its own. It shows elements common to the Western and Eastern Ghats and is a meeting ground for the vegetation of these two areas.

Problems Concerning Future Indian Hepaticology

(1) *Regional floras, State floras and flora of the Country*

Whereas excellent attempts have been made by the bryologists in the European Continent as well as in America to elucidate the distribution, ecology and frequency of species of hepatics growing in various regions of their respective countries thereby presenting a comprehensive account of their hepatic flora, in India no such attempts have seriously been made after the excellent publications on the hepatics of the Western Himalayas and the Punjab plains by Kashyap (1929; 1932). This has naturally resulted in a most inadequate comprehension of our hepatic flora which is bound to be sufficiently luxurious and interesting in view of the diverse geographical climates and favourable habitats for the growth of these plants. As I have suggested earlier in my address, I feel that the most urgent need is to prepare regional floras, floras of the various States and finally a complete flora of the country. The elaborate data thus accumulated will not only be of immense help in preparing a complete account of the hepatic vegetation but will be equally helpful in studying the remarkable distribution patterns and common elements of our flora with other countries and perhaps will be helpful in elucidating some of the interesting distribution patterns connected with other groups of plants as well.

(2) *Preparation of Monographs*

Another very important aspect, which has been neglected so far, is the preparation of monographic account of various genera growing in India. Although such an investigation entails accumulation of comprehensive as well as intensive and extensive collection of plant materials, it is extremely useful for elaborate comprehension and scientific approach for future work. I have particularly kept this aspect of the study in view while making collections from various parts of the country and a large number of genera are represented in my collection for such investigations.

From the results obtained so far from a detailed study of a single genus *Riccia* (Pandé and Udar, 1957 *b*, 1957 *c* and Udar, 1957 *a*) in India, I strongly feel that most of our genera stand in need of detailed critical study and revision. For example, several species of *Riccia* described from India under different names on critical examination turned out to be identical (Pandé and Udar, 1957 *a*, *b*; Udar, 1957 *a*), quite a few newly instituted species were found to be mere synonyms of some older species while a new species discovered from Runneymede, Madras State, has proved to be extremely interesting in having characteristic tubercular thickenings on the walls of the cells of some of the assimilatory filaments (Pandé and Udar, 1957 *a*), earlier described in another species of this type *R. bistriata* (Evans, 1919) from

Peru. Besides, an interesting distribution of the genus is revealed. *Riccia* is represented in our flora by about 25 species and includes such European elements as *R. huebeneriana*, *R. sorocarpa*, *R. warnstorfii*, and *R. crozalsii* (Udar, 1956; Udar, 1957 *b*); *R. discolor* and *R. plana*, common to Africa (Pandé and Udar, 1957 *c*); *R. billardieri* and *R. gangetica* common to Java (Udar, 1957 *a*); *R. sorocarpa* and *R. huebeneriana* common to Japan, *R. curtisii*, *R. crystallina*, *R. frostii* cosmopolitan in distribution and some endemic species as *R. cruciata* Kash., *R. pathankotensis* Kash., *R. melanospora* Kash. (Kashyap, 1929); *R. aravalliensis* Pandé *et* Udar (Pandé and Udar, 1957 *a*) and *R. tuberculata* Pandé *et* Udar (Pandé and Udar, 1957 *c*).

In the frequency of species the genus *Riccia* in India is probably next only to America and Africa and the genus is represented in our flora by such simple species as *R. crystallina* and *R. frostii* and such xeromorphic species as *R. discolor*, *R. melanospora* and *R. tuberculata* showing thickenings on some of the cells of the assimilatory zone.

(3) *Culture Studies*

Yet another interesting aspect of bryological studies, which awaits careful investigation, is the study of the hepatics under culture conditions, including the sporeling patterns, and their enormous capacity of vegetative reproduction and regeneration. The latter is particularly fascinating and has been extensively worked out in the Acrogynous Jungermanniales by Fulford (1956) and only recently some attention has been paid to this aspect in India by Mehra and Kachroo (1951, 1952), Kachroo (1955, 1955 *a*, 1956, 1956 *a*) and in my laboratory (Udar, 1957 *c*, *d*; Udar and Singh, 1957; Udar, unpublished data).

As far back as 1900 Goebel (1900), from his study of sporelings in *Preissia commutata*, observed that during germination often secondary germ tubes developed from the germ disc which organized at their apex another disc. The formation of the elongated germ tubes was ascribed to weak illumination. Such stages have repeatedly been noticed in culture in other hepatics, *e.g.*, *Riccia* (Pandé, 1924), *Targionia* (Campbell, 1918), etc. In *Targionia*, Campbell (1918) observed that quite often the germ tube is suppressed and instead a multicellular germ disc develops. From the latter a germ tube is secondarily formed which later produces another disc. Stages as these, according to him, may be considered to represent a protonema from which the gametophyte develops.

In 1924 I observed for the first time a peculiar behaviour of the sporelings in *R. frostii*, grown under blue glass covers. I could not fully account for this peculiar behaviour then. Studies, now in progress in my laboratory, have repeatedly shown this phenomenon in several genera. In *R. crystallina* (Udar, 1957) and *Notothylas indica* (Udar and Singh, 1957) the thalli show copious regeneration potentiality and the regenerants largely follow the sporeling pattern. In *Asterella*

angusta and *Plagiochasma intermedium* (Udar, unpublished) a large number of adventitious branches develop from thalli which later produce regenerants resembling sporelings. It seems reasonably certain that the formation of secondary tubes, a process which may be repeated several times in succession, each organizing a multicellular disc, merely represent a regeneration phenomenon induced by several causes, *i.e.*, weak illumination, contaminants or by excessive moisture, injury, etc., acting collectively or independently.

(4) *Cytotaxonomy and hybridization*

The study of the hepatics will not be complete without a thorough Cytological and Cytogeographical study of the various genera. This aspect has been rather much neglected in India and except for some excellent contributions by Mehra (1938, 1948, 1953) and Mahabalé (1942, 1947) and some recent contributions from my laboratory (Udar and Chopra, 1957), there is an appalling paucity of such work. Culture and Cytological studies have very often yielded valuable data in determining the taxonomic status of species, an excellent example of which is the segregation of the *Riccia fluitans*—complex into 4 species (Lorbeer, 1934), (Müller, 1940, 1941), and lastly, as ably pointed out by Herman Persson (1956), in his learned lecture at the University of Connecticut's main campus at the Annual Convention of the American Institute of Biological Sciences, " the close study of the hydridization of bryophytes in nature combined with cultivation experiments is still waiting upon the bryologist courageous enough to start ".

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EXPLANATION TO MAP I

(Names of places indicated by numbers)

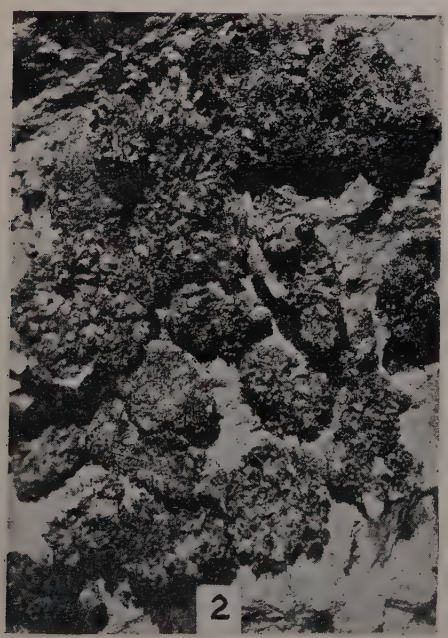
1. Srinagar	2. Simla	3. Jamnotri
4. Gangnani	5. Chakrata	6. Mussoorie
7. Dehra Dun	8. Suki	9. Harsil
10. Uttar Kashi	11. Bhatwari	12. Gangotri
13. Gaumukh	14. Joshimath	15. Rudraprayag
16. Milam	17. Phurkia	18. Munsyari
19. Girgaon	20. Kapkot	21. Bageshwar
22. Mugu	23. Chakhali	24. Dhurchi Lake
25. Magkarpali	26. Jumla	27. Silgarhi
28. Baglung	29. Pokhara	30. Udhan Pokhara
31. Chumle	32. Phaloot	33. Raman
34. Sandakpu	35. Manebhanjan	36. Jorpokhari
37. Rimbick	38. Badampton	39. Darjeeling
40. Siliguri	41. Silghot	42. Gauhati
43. Shillong	44. Dawki	45. Cherrapunji
46. Mauflong	47. Tripura	48. Parasnath
49. Calcutta	50. Dacca	51. Patna
52. Lucknow	53. Bhopal	54. Pachmarhi
55. Saugor	56. Amarkantak	57. Mt. Abu
58. Jodhpur	59. Mehsana	60. Rajkot
61. Dwarka	62. Bombay	63. Lonavala
64. Mahabaleshwar	65. Hyderabad	66. Gersoppa Falls
67. Shimoga	68. Agumbe	69. Bhadravati

70. Karkal	71. Kuduremukh	72. Mangalore
73. Mercara	74. Bangalore	75. Mysore
76. Madras	77. Yercaud	78. Ootacamund
79. Devala	80. Coimbatore	81. Nilgiri
82. Dodabetta	83. Nagapatam	84. Kodaikanal
85. Madura	86. Shenbaganur	87. Rameshwaram
88. Maunas	89. Colombo	90. Kandy
91. Pedro's Peak	92. Nuwara Eliya	93. Adorus
94. Gale	95. Matale	

Explanation of Plate I

Fig. 1. Field photograph of *Anthoceros gemmulosus* (Hatt.) Pandé Comb. nov. above Munsyari, Melam. The coin in the centre (below) was utilised for magnification.

Fig. 2. *Frullania* sp. growing on rocks—between Someshwar and Bageshwar.



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FOSSIL DIATOMS FROM COLEBROOK ISLAND

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(Received for publication on December 20, 1957)

Marine fossil diatoms have been known to occur in India since 1851. But so far only the Nancoori deposits in Nicobars have been worked out in considerable detail.

Ehrenberg (1851, 1854–56) was the first to record marine fossil diatoms from India in what he called 'Polycystine rocks' from the Nancoori Island deposits. A second major collection of the same is reported in the Novara Expedition (*see* Grunow, 1867). Based on this collection many species were described by Grunow (Grunow, 1867; *see* also van Heurck, 1880–85; Cleve, 1883; Pentocsek, 1889). A few species were included by Schmidt in his *Atlas* (1885–1944). Cleve and Möller (1878) and Tempere and Peragallo (1915) have also distributed slides of this material together with a list of species found in them. Besides these, accounts or original records of a few species from the Nancoori are also found in Rattray (1889) and Cleve (1894, 1895). Recently Ghosh and Maitra (1947) have also studied these deposits again. A list of the forms known previously from the Nicobar Islands is given in the Appendix.

Recently Kolbe (1957) reported a number of diatoms he found in the cores taken from the Indian Ocean bottom from near Ceylon, Maldives, etc. Not much is known of the marine fossil deposits from the other regions of India and the neighbourhood.

Boileau (1950) and Jacob and Shrivastava (1952) have pointed out the presence of fossil diatoms in the Colebrook Island of the Ritchie's Archipelago in the Andamans. However, the fossil diatoms found in this deposit has not been systematically worked out. Hence a study of the diatoms found in this deposit has been taken up by the writers.

Material and Methods

The Director, Geological Survey of India, very kindly sent some material from the fossil deposit in the Colebrook Island. The present account is based on a study of this material.

Cleaning of the Diatomaceous earth was done by adapting a method given by Johansen (1940). The details of the procedure adopted are given below. A portion of the material with about thrice its

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quantity of sodium acetate was taken in a flask, moistened with distilled water and boiled for about ten minutes. Then the flask was kept aside undisturbed for cooling. A few crystals of sodium acetate were added to the cooled solution to begin crystallisation of the dissolved sodium acetate. The crystallisation process served to loosen up the fossil material. Now the sodium acetate was removed by repeated washings with boiling water.

The material was heated with dilute hydrochloric acid. After the effervescence had ceased concentration of hydrochloric acid was gradually increased to 50% and heating continued for about three hours. After decanting the hydrochloric acid, sulphuric acid was added and the material was again heated for about one hour. The residue was finally cleaned with concentrated sulphuric acid and potassium dichromate for about half an hour. After cooling, the acid was completely removed by repeated washing with distilled water. The cleaned material was ultimately preserved in 70% alcohol.

A dilute suspension of the cleaned material was spread on the slides, and the slides dried over a gentle flame. Permanent preparations were directly made with balsam or diaphane.

Description of the Species

ROSSIELLA gen. nov.

Valvæ elongato-ellipticæ, apicibus fastigatis rotundatisque, superficies leniter convexa vel fere plana; area centralis atque rosula absunt; areolæ polygonales; dispositio marginalis distincta nulla.

Species typica: sequens.

Rossiella paleacea (Grun.) Comb. nov.

[= *Stoschia* (?) *paleacea* Grunow in van Heurck, 1880–85.

= *Coscinodiscus paleacea* (Grun.) Rattray, 1889.]

ROSSIELLA gen. nov.

Valve elongately elliptical, with tapering rounded ends; valve surface slightly convex or almost flat; central area and rosette absent; areolæ polygonal; no distinct marginal arrangement.

Type species: *Rossiella paleacea* (Grun.) Comb. nov.

[= *Stoschia* (?) *paleacea* Grunow in van Heurck, Synopsis des Diatomées de Belgique, 1883, Plate 128, Fig. 6.

= *Coscinodiscus paleacea* (Grun.) Rattray, 1889.]

Rossiella paleacea (Grun.) Comb. nov.

(Text-Fig. 1)

Valve elongately elliptical, with tapering rounded ends, length 25–76 μ, breadth 10–18 μ; valve surface slightly convex or almost

flat; central area and rosette absent; areolæ polygonal uniform in size, 5–7 in 10 μ, irregularly arranged; no distinct marginal arrangement; apertures distinct.

The species, when first published, was doubtfully referred to *Stoschia* Jan. ex van Heurck by Grunow as *S.* (?) *paleacea*. Rattray (1889), however, placed the species under *Coscinodiscus*. It may be pointed out that the species differs markedly in shape from the rest of the species of *Coscinodiscus*. One is prone to agree with Grunow on the separation of this species from *Coscinodiscus*. A new genus is created here to receive this species and is called after Mr. R. Ross of the British Museum. This new genus will bear the same relationship to *Coscinodiscus* as *Druridgea* Donk. bears to *Melosira*. Ag.

COSCINODISCUS Ehrbg.

C. lewisianus Grev.

(Text-Fig. 6)

Schmidt, *Atlas*, 1876, Plate 66, Fig. 12; Rattray, *Revis. Coscin.* 1889, 598; De Toni, *Syll. Alg.*, 1891–94, 1302.

Valve elliptical with rounded ends, 24–56 μ long, 12–30 μ broad; no central space or rosette, but centre distinguishable by irregularly arranged large areolæ; areolæ rounded, 4–5 in 10 μ, arranged in rows, rows straight and slightly curved parallel to the apical axis; the marginal areolæ smaller, 8–9 in 10 μ, arranged closely in oblique decussating rows; striæ present, 14–15 in 10 μ; border indistinct.

This species agrees in all respects with the type except in that the valve is smaller in size.

C. superbus Hardm.

(Text-Fig. 2)

Rattray, *Revis. Coscin.*, 1889, 458; De Toni, *Syll. Alg.*, 1891–94, 1207.

= *Cestodiscus superbus* (Hardm.) Schmidt, *Atlas*, 1888, Plate 138, Fig. 13.

Valve diam. 34–45 μ, surface convex in the centre; central space small, indefinite; punctæ round, central ones larger, 5–6 in 10 μ, the marginal ones smaller, 8–9 in 10 μ; in the central region punctæ arranged in indistinct concentric rows, in the marginal band in indistinct oblique decussating rows; distinct hyaline interspaces present, largest towards centre; apiculi prominent, inserted at the inner edge of the marginal band at the interval of 7–8 μ; striæ evident, 15 in 10 μ.

Only one valve of this species was seen but identification was done by comparison with authentic material in Cleve and Möller, slide No. 162.

C. asteromphalus Ehrbg.

(Text-Fig. 9)

Schmidt, *Atlas*, 1878, Plate 63, Fig. 5; De Toni, *Syll. Alg.*, 1891–94, 1268; Mann, *Diat. Albat.*, 1907, 247; Hustedt, *Kieselalgen*, Teil I, 1930, 452, Fig. 250; Subrahmanyan, *Mar. Plank. Diat.*, 1946, 99, Figs. 62–65.

Valve diam. 126–142 μ; central hyaline area present; areolæ polygonal, gradually increasing towards periphery, largest in the submarginal region, 3–4 in 10 μ, areolæ near the margin smaller, 6–10 in 10 μ; apertures large, distinct.

CRASPEDODISCUS Ehrbg.

C. coscinodiscus Ehrbg.

(Text-Fig. 3)

Schmidt, *Atlas*, 1878, 1893, Plate 66, Figs. 3–5 and Plate 184, Fig. 4; De Toni, *Syll. Alg.*, 1891–94, 1199.

Valve diam. 35–59 μ; central region convex; areolæ polygonal, larger in the marginal region, 3–4 in 10 μ, smaller in the central portion, 6–7 in 10 μ; pores distinct; margin striated, striæ 6–7 in 10 μ.

STICTODISCUS Grev.

S. nankoorensis Grev.

(Text-Fig. 5)

Schmidt, *Atlas*, 1876, Plate 74, Figs. 2, 3; De Toni, *Syll. Alg.*, 1891–94, 1315.

Valve diam. 35–93 μ, surface flat, marked with arcuate lines; lines radial and dichotomous in the subcentral and marginal regions, reticulate in the centre, sometimes transverse lines joining the radial ones present; punctæ rounded, uniform in size, 3–4 in 10 μ, arranged in radial rows alternating with the radial lines, secondary oblique rows present, in the centre punctæ fewer, without arrangement.

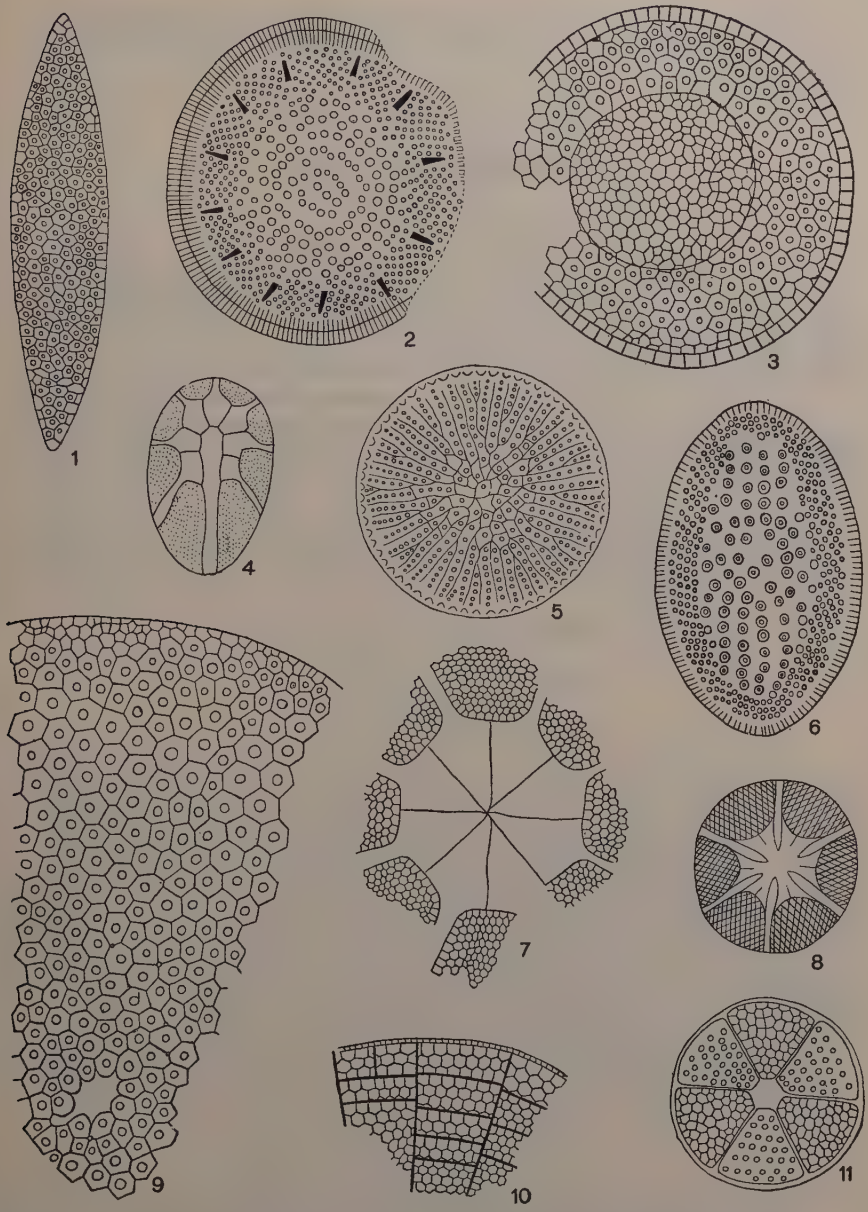
ARACHNOIDISCUS Ehrbg.

A. ornatus Ehrbg.

(Text-Fig. 10)

Schmidt, *Atlas*, 1876, Plate 73, Figs. 4–6; De Toni, *Syll. Alg.*, 1891–94, 1311; Karsten, *Bacillariophyta*, 1928, 216, Fig. 225.

Valve surface divided by radial and transverse costæ; near the margin of the valve the radial costæ alternate with one or two short secondary costæ; areolæ polygonal, 6–10 in 10 μ, arranged in radial as well as tangential rows.



TEXT-FIGS. 1–11. Fig. 1. *Rossiella paleacea* (Grun.) Comb. nov. Fig. 2. *Coscinodiscus superbus* Hardm. Fig. 3. *Craspedodiscus coscinodiscus* Ehrbg. Fig. 4. *Asteromphalus flabellatus* (Bréb.) Grev. forma. Fig. 5. *Stictodiscus nankoorensis* Grev. Fig. 6. *Coscinodiscus lewisianus* Grev. Fig. 7. *Asterolampra marylandica* Ehrbg. Fig. 8. *Asterolampra nicobarica* Grun. forma. Fig. 9. *Coscinodiscus asteromphalus* Ehrbg. Fig. 10. *Arachnoidiscus ornatus* Ehrbg. Fig. 11. *Actinoptychus undulatus* (Bail.) Ralfs. (All figures, × 1,000.)

Only small pieces of the valve were found. The identification is based on comparison with the authentic material in Cleve and Möller, slide No. 162.

ACTINOPTYCHUS Ehrbg.

A. undulatus (Bail.) Ralfs.

(Text-Fig. 11)

De Toni, *Syll. Alg.*, 1891–94, 1372; Peragallo, M. H., *Diat. Mar. France*, 1897–1908, 407, Plate 111, Fig. 1; Karsten, *Bacillariophyta*, 1928, 219, Fig. 236; Hustedt, *Kieselalgen*, Teil I, 1930, 475, Fig. 264; Hanna, *Diat. Sharktooth Hill*, 1932, 172; Subrahmanyan, *Mar. Plank. Diat.*, 1946, 105, Fig. 82.

Valve diam. 17–24 μ; sectors six, three depressed ones alternating with the other three; central polygonal hyaline area present; areolæ polygonal, 6–7 in 10 μ; margin narrow, simple; papillæ not clearly seen.

This form comes very near *A. undulatus*, but in the three specimens observed no papillæ were clearly distinguishable. Hence the species is tentatively identified as *A. undulatus*.

ASTEROLAMPRA Ehrbg.

A. marylandica Ehrbg.

(Text-Fig. 7)

Schmidt, *Atlas*, 1874, Plate 137, Figs. 19–21; Rattray, *Revis. Coscin.*, 1889, 641; De Toni, *Syll. Alg.*, 1891–94, 1403; Peragallo, M. H., *Diat. Mar. France*, 1897–1908, 404, Plate 110, Fig. 2; Karstern, *Bacillariophyta*, 1928, 221, Fig. 240 B; Hustedt, *Kieselalgen*, 1930, 485, Figs. 270, 271; Cupp, *Mar. Plank. Diat.*, 1943, 68, Fig. 31.

Valve diam. about 50 μ; central areolate area absent; rays eight conspicuously ramose near their inner ends, straight or slightly wavy; compartments eight with transversely truncate inner ends, varying in breadth; areolæ distinct, polygonal, 6–10 in 10 μ, those along the inner margin of the compartments slightly larger.

No full specimens of this species were found. The diatom comes near var. *ramosa* Ratt.

A. nicobarica Grun. forma

(Text-Fig. 8)

Rattray, *Revis. Coscin.*, 1889, 639; De Toni, *Syll. Alg.*, 1891–94, 1402.

Valve diam. 21 μ; central areolate area absent; radial subclavate hyaline areas extending from the subcentral region to almost near the border; compartments six, reaching about $\frac{1}{2}$ of the radius inwards,

with convex inner ends; rays arising from the inner ends of the compartments, not meeting in the centre; areolæ indistinct.

It differs from the type in being smaller and having indistinct areolæ.

ASTEROMPHALUS Ehrbg.

A. flabellatus (Bréb.) Grev. forma

(Text-Fig. 4)

Schmidt, *Atlas*, 1876, Plate 38, Fig. 10; Rattray, *Revis. Coscin.*, 1889, 662; De Toni, *Syll. Alg.*, 1414; Peragallo, M. H., *Diat. Mar. France*, 1897–1908, 406, Plate 110, Figs. 4, 5; Hustedt, *Kieselalgen*, 1930, 498, Fig. 279; Subrahmanyan, *Mar. Plank. Diat.*, 1946, 105, Figs. 81, 85.

Valve oval or flabelliform, 25–30 μ long, 17–18 μ broad; centrolateral area subclavate, the sides almost parallel towards the centre, inner end more or less rounded; rays straight or slightly curved; the compartments reaching 2/5–2/3 of radius inwards, their inner ends conical, in some transversely truncate on either side of the ray; areolæ obscure; the intervals narrowing outwards, extending to the border.

This form differs from the type in the valve being very small.

TRICERATIUM Ehrbg.

T. cancellatum Grev.

(Text-Fig. 13)

De Toni, *Syll. Alg.*, 1891–94, 937.

Valve triangular; length of one side 24·5 μ; valve surface distinguished into a central convex, not clearly delimited zone and a marginal region; areolæ 6–10 in 10 μ, arranged in regular radial rows of three along the sides, at the angles irregularly grouped; in the central zone areolæ larger, fewer and irregularly distributed.

This specimen, according to the description of De Toni, comes nearest to *T. cancellatum*. Since only one specimen was found, and there are no figures for reference, identification is tentative.

HEMIAULUS Ehrbg.

H. polymorphus Grun.

(Text-Fig. 20)

Schmidt, *Atlas*, 1874, Plate 143, Figs. 11–13; De Toni, *Syll. Alg.*, 1891–94, 851; Hanna, *Cretaceous Diatoms*, 1927 *a*, 114, Plate 18, Fig. 10; Hustedt, *Kieselalgen*, Teil I, 1930, 880; Hanna, *Diat. Sharktooth. Hill*, 1932, 193, Plate 11, Fig. 7.

Valve diam. about 26 μ; valve with two long processes, 33·5 μ long, parallel to pervalvar axis; end portion of each process hyaline, with a short indistinct spine; punctæ 8–9 in 10 μ, arranged alternately in two rows along the long axis of the processes, irregularly arranged in other parts.

This diatom appears to resemble var. *frigida*. But in the absence of adequate number of specimens, the varietal identification cannot be definitely made.

GEPHYRIA Arnott

G. media Arnott

(Text-Figs. 17, 18)

De Toni, *Syll. Alg.*, 1891–94, 775; Schmidt, *Atlas*, 1902, Plate 231, Figs. 18–21 and Plate 232, Figs. 7–13; Hustedt, *Kieselalgen*, Teil II, 1930, 10, Fig. 544.

Valve linear, with rounded ends, 17–22 μ broad; valves dissimilar, one with and the other without, two large end pores; a narrow pseudoraphe present, ending in a round subterminal hyaline area; the transverse costæ on either side of the pseudoraphe opposite to each other, about 5–7 in 10 μ; on either side of the pseudoraphe two longitudinal rows of large foramina, transversely oval, 5–7 in 10 μ; two rows of punctæ in each costæ, punctæ of one row alternating with the other, 14–15 in 10 μ.

PLAGIOGRAMMA Grev.

P. tesselatum Grev.

(Text-Fig. 14)

Schmidt, *Atlas*, 1874, Plate 209, Figs. 42–47; De Toni, *Syll. Alg.*, 1891–94, 719; Hanna and Grant, *Maria Madre Isl.*, 1926, 162, Plate 19, Fig. 10.

Valve linear-lanceolate with sides slightly convex, 71 μ long and 14 μ broad; the ends tapering, rounded, and having a more or less oval hyaline area; central area present, transversely oval; areolæ obtusely quadrangular, on the average 4–5 in 10 μ, but a few irregularly placed ones much smaller; six longitudinal rows of areolæ, the two marginal ones continuous almost throughout the length of the valve, the median four are interrupted by the central end polar hyaline areas.

RHAPHONEIS Ehrbg.

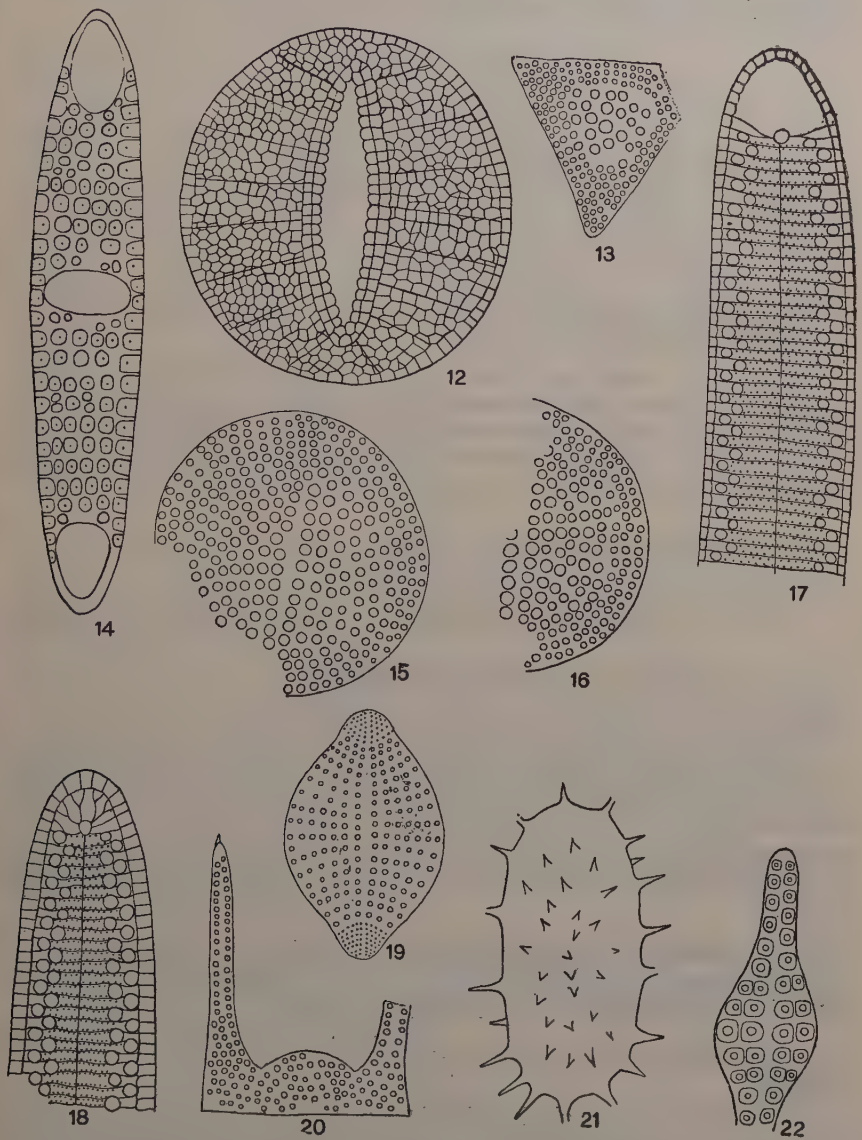
R. elegans Pant. & Grun. forma

(Text-Fig. 22)

Hanna, *Diat. Sharktooth Hill*, 1932, 213, Plate 15, Figs. 9–10.

Valve flat, elongated, with rounded ends, length 24–37 μ, maximum breadth 9–11 μ, valve slightly broader in the central portion; areolæ

obtusely polygonal, heavy and large, 5–7 in 10 μ, having distinct central apertures, 2–4 in each transverse row; pseudoraphe narrow, distinct.



TEXT-FIGS. 12–22. Fig. 12. *Campyloneis grevillei* (W. Sm.) Grun. var. *regalis*. Fig. 13. *Triceratium cancellatum* Grev. Fig. 14. *Plagiogramma tesselatum* Grev. Figs. 15, 16. *Rhaphoneis cocconeiformis* (Schmidt) Hanna and Grant. Figs. 17, 18. *Gephyria media* Arnott. Fig. 19. *Rhaphoneis amphiceros* Ehrbg. Fig. 20. *Hemiaulus polymorphus* Grun. Fig. 21. *Xanthiopyxis oblonga* Ehrbg. Fig. 22. *Rhaphoneis elegans* Pant. and Grun. forma. (Figs. 15, 16 and 22, × 1,600, the rest, × 1,000.)

This specimen differs from *R. elegans* Pant. and Grun. in having obtusely polygonal markings, large and distinct apertures, and less number of markings in the central transverse rows.

R. amphiceros Ehrbg.

(Text-Fig. 19)

De Toni, *Syll. Alg.*, 1891–94, 699; Schmidt, *Atlas*, 1911, Plate 269, Figs. 45, 46, 50–55; Peragallo, M. & H., *Diat. Mar. France*, 1901, 329, Plate 83, Figs. 15–23; Karsten, *Bacillariophyta*, 1928, 262, Fig. 338; Hanna and Grant, *Maria Madre Isl.*, 1926, 165, Plate 20, Fig. 8; Hustedt, *Kieselalgen*, Teil II, 1930, 174, Fig. 680; Hanna, *Diat. Shark-tooth Hill*, 1932, 211, Plate 18, Figs. 3–5; Subrahmanyan, *Mar. Plank. Diat.*, 1946, 165, Figs. 340, 341; Gonzalves and Gandhi, *Diat. Bombay and Salsette*, 1952, 125, Fig. 13.

Valve flat, elongated, length 29·5 μ, breadth 20 μ, very broad transversely; sides rounded and slightly depressed near the ends to demarcate the obtusely rounded ends; punctæ distinct, rounded, 6–7 in 10 μ, arranged in transverse rows gently curved away from the transverse axis towards the outer ends; pseudoraphe narrow, distinct.

R. cocconeiformis (Schmidt) Hanna & Grant

(Text-Figs. 15, 16)

Hanna and Grant, *Maria Madre Isl.*, 1926, 165, Plate 20, Fig. 9.

= *Coscinodiscus cocconeiformis* Schmidt, *Atlas*, 1878, Plate 58, Figs. 23–28; Rattray, *Revis. Coscin.*, 1889, 599; De Toni, *Syll. Alg.*, 1891–94, 1302; Mann, *Diat. Albat.*, 1907, 248.

Valve circular, bilaterally symmetrical, diam. 21 μ; both valves similar; areolæ somewhat rounded or polygonal, 9–10 in 10 μ, arranged in radial rows; pseudoraphe present, short, narrow.

Hanna and Grant have reported the absence of pseudoraphe, but in this form, just as in the figures of Schmidt's *Atlas*, a pseudoraphe is present.

This diatom was first described by Schmidt as *Coscinodiscus cocconeiformis*, and later by Rattray. But Hanna and Grant (1926) transferred the species to the genus *Rhaphoneis*.

The species has not been recorded from India from any fossil deposit.

CAMPYLONEIS Grun.

C. grevillei (W. Sm.) Grun. var. *regalis* Grev.

(Text-Fig. 12)

De Toni, *Syll. Alg.*, 1891–94, 439; Cleve, *Naviculoid Diatoms*, 1895, 167; Peragallo, M. & H., *Diat. Mar. France*, 1897, 23, Plate 4,

Figs. 18–21; Karsten, *Bacillariophyta*, 1928, 271, Fig. 359 A; Hustedt, *Kieselalgen*, Teil II, 1930, 323, Fig. 782.

Valve almost orbicular, diam. along pseudoraphe 44·5 μ and across it 42 μ; pseudoraphe distinct broad lens-shaped, extending for about $\frac{3}{4}$ of the median axis; areolæ polygonal, 6–7 in 10 μ, arranged in distinct or obscure radial rows; 3–4 rows are grouped in zones marked by radial costæ, two rows of areolæ surround the pseudoraphe; margin narrow, striated, striæ 6–7 in 10 μ.

XANTHIOPYXIS Ehrbg.

X. oblonga Ehrbg.

(Text-Fig. 21)

De Toni, *Syll. Alg.*, 1891–94, 1155; Hanna and Grant, *Maria Madre Isl.*, 1926, 170, Plate 21, Fig. 11; Hanna, *Tertiary Diatoms*, 1927 *b*, 124; Hanna, *Sharktooth Hill*, 1932, 226.

Valve oblong with more or less linear sides and rounded ends, 30–39 μ long, 15–17 μ broad; surface covered with irregularly distributed spines, spines 2–2·5 μ long.

Summary

In all 20 forms belonging to 14 genera have been described above. Many of these species have been recorded earlier from the Miocene deposits of Nancoori Island. Only seven are new records to the fossil deposits of the Andamans and Nicobar Islands.

Acknowledgments

Dr. P. Bourrelly of Lab.-Crypt. Mus. Hist. Nat., Paris, very kindly sent Cleve and Möller's slides of Nancoori deposits. Prof. Rev. Fr. H. Santapau very kindly rendered into Latin the diagnosis for *Rossiella*. Mr. R. Ross very kindly permitted us to go through the slides and records of Nancoori deposits. To these gentlemen the authors express their grateful thanks. The authors wish to gratefully acknowledge the help rendered by the Director, Geological Survey of India, by way of material and literature.

The authors are grateful to the Ministry of Education, Government of India, for special grant-in-aid for literature, etc., to one of us (T. V. D.) and to Dr. S. B. Saksena, Head of the Department of Botany, University of Saugar, for facilities.

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APPENDIX

The following is a list of species of fossil diatoms recorded from Nancoori Islands. The list has been compiled from published works and to this are also added diatoms from Nancoori, identified and deposited by Comber, Adam, Stuart and Baxter in the British Museum of Natural History. Thanks are due to Mr. R. Ross of the British Museum for his kind help and permission to refer to their lists and slides.

Actinocyclus ehrenbergii Ralfs.
A. ellipticus Grun.
A. ovalis (Norm.) Grun.
A. roperii (Breb.) Kitt.
Actinoptychus capensis Grun.
A. pulchellus Grun.
A. splendens (Shabd.) Ralfs.
A. undulatus (Bail.) Ralfs.
A. wittianus Jan.
Arachnoidiscus ehrenbergii Bail.
A. indicus Ehrbg.
A. ornatus Ehrbg.
Asterolampra ambigua Grev.
A. dubia Grev.
A. affinis Grev.
A. grevillei (Wall.) Grev.
A. marylandica Ehrbg.
A. nicobarica Grun.
Asteromphalus nankoorensis Grun.
A. variabilis (Grev.) Rattray
Aulacodiscus amœnus Grev.
A. angulatus Grev.
A. argus (Ehrbg.) Schmidt
A. crux Ehrbg.
A. kittoni Arnott
A. kittoni var. *johnsonii* (Arnott) Ratt.
A. macreœnus Grev.
A. orientalis Grev.
A. parvulus Ratt.
A. scaber Ralfs.
Auliscus cœlatus Bail. f. *major* Schmidt
A. cœlatus var. *rhipis* Per.
A. pruniosus Bail. var.
A. stockhardtii Jan.
Campyloneis grevillei (W. Sm.) Grun.
Climacosira mirifica (W. Sm.) Grun.
Cocconeis dirupta var. *sigma* Pant.
C. pellucida Grun.
——— var. *nankoorensis* Grun.
Coscinodiscus asteromphalus Ehrbg. var. *hybrida* Grun.
C. biangulatus Schmidt
C. curvatulus Grun. var. *minor* Grun.
C. ellipticus Grun.
C. excentricus Ehrbg.
C. gigas Ehrbg.
C. interlineatus Ratt.
C. leptopus Grun.
C. lewisianus Grev.
C. lineatus Ehrbg.
C. marginatus Ehrbg.
C. minor Ehrbg.
C. nodulifer Jan.
C. odontodiscus Grun. var. *subsubtilis* Ratt.
C. ovalis Ratt.
C. paleaceus (Grun.) Ratt.
C. partitus Grove and Stuart
C. plicatus Grun.
C. punctatus Ehrbg.
C. radiatus Ehrbg.
——— var. *minor* Schmidt.
C. robustus Grev.
C. rex Wallich
C. subtilis Ehrbg.
——— var. *scabra* Ratt.
C. superbus Hardm.
C. vetustissimus Pant.
Craspedodiscus coscinodiscus Ehrbg.
——— ——— var. *nankoorensis* (Grun.) T. and P.
C. insignis Schmidt
C. nicobaricus Ehrbg.
Denticula nicobarica Grun.
Diploneis interrupta (K.) Cl.
D. campylodiscus (Grun.) Cl.
Enditctya oceanica Ehrbg.
Euodia gibba Bail.
Eupodiscus jonesianus Grev.
Fragilaria (?) *nankoorensis* Grun.
Gephyria media Arnott
——— ——— var. *ornata* (Grun.) Schmidt
Grammatophora lyrata Grun.
Glyphodesmis nancoorense (Grun.) Kolbe
Hemiaulus ornithocephalus Grev., f. *nicobaricus* Grun.
Isthmia enervis Ehrbg.
——— ——— var. *nankoorensis* Grun.
Mastogloia splendida (Greg.) Cl.
Navicula formosa Greg.
N. forcipata Grev., var. *nankoorensis* Grun.
N. gemmata Grev. var. *biseriata* Grun.
N. henedeyi W. Sm.

N. lyra Ehrbg.
N. prætexta Ehrbg.
N. prisca Schmidt
N. pusilla W. Sm.
Orthoneis barbadensis (Grev.) Grun. var. *nankoorensis* Grun.
Plagiogramma polygibbum Cleve and Grove.
P. nankoorense Grun.
Pleurosigma balticum (Ehr.) W. Sm.
P. nicobaricum Grun.
P. angulatum (Quek.) W. Sm.
Podocystis spathulata (Shabd.) W. H.
Podosira argus Grun.
Stephanopyxis minuta Grev.
S. turris (Grev.) Ralfs.
S. nankoorensis Hust.
S. pandura Per.
Stictodiscus californicus Grev.
——— ——— var. *aggregata* T. & P. (?)
S. nankoorensis Grun.
S. novaræ Cleve
S. rota (Ehrbg.) Grev.
Syringidium americanum W. Sm.
Triceratium antedeluvianum (Ehrbg.) Grun.
T. arcticum Brightw.
T. ——— var. *trigona* Per. M.
T. ——— var. *pentagona* (Per.) Per.
T. brœckii Leud.-Fortm.
T. cancellatum Grev.
T. cinnamomeum Grev.
T. concinum Grev.
T. distinctum Jan.
T. favus Ehrbg.
T. fimbriatum Wall.
T. grande Brightw. (?)
T. madagascarense Grun.
T. megastomum Brightw.
T. moronense Grev. var. *nicobarica* Grun.
T. nankoorense Grun.
T. nicobaricum Grun.
T. obscurum Grev. f.
T. obtusum Ehrbg.
T. quinquelobatum Grev.
T. receptum Schmidt.

A NEW SPECIES OF *DISCOSIELLA* FROM ASSAM

By V. Agnihothrudu

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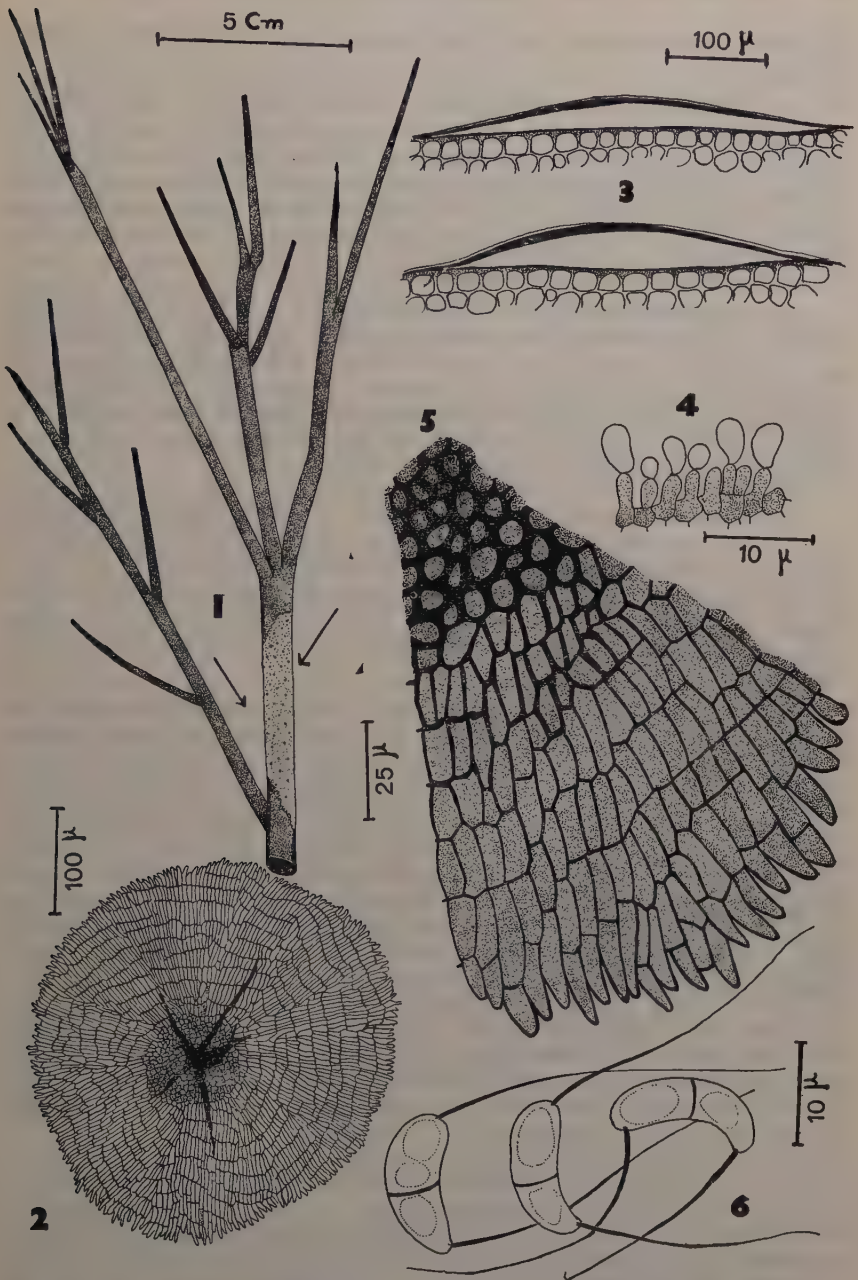
(Received for publication on November 5, 1957)

The didymosporous leptostromataceous fungus for which a new name is proposed in this brief paper was first observed in the month of November, 1956 on dead tea twigs found on some of the bushes growing in the experimental plots of Tocklai Experimental Station. Only a limited number of stem pieces bearing the fructifications was available and the fungus was not observed later in spite of repeated searches by the writer. In some instances the fungus was found in association with *Pestalozzia* sp. or *Glomerella cingulata* (Stonem.) Spauld. and v. Schrenk. (= *Glomerella major* Tunstall) *sensu* Arx and Müller (1954). It is rather difficult to say which of these organisms was responsible for the death of the twigs.

The fungus was found to form irregular, ill-defined spots that completely encircle the twigs. The pycnidia are discrete and subcuticular, disc-shaped or slightly elliptic with a well developed scutellum on the top and are seated on a meagerly formed subiculum. They are astomate and dehiscence takes place by an irregular slit formed on the top. The spores are produced on short unbranched conidiophores and are allantoid to saucer-shaped, uniseptate and on either end subterminally uniciliate. The spores germinate readily in distilled water producing one or two germ tubes within 14 hours after incubation but, however, all attempts by the writer to grow the fungus on a variety of synthetic and natural media met with no success at all.

The fungus collected by the author fits in the genus *Discosiella* (Sydow, 1912) belonging to the Leptostromataceæ of the Sphæropsidales in all the characters except in the shape of the spores and in the insertion of cilia. Sydow's description of the spores is as follows: " sporulæ hyalinæ, cylindraceæ, 1-septatæ, utrinque 1-ciliata " (Saccardo, 1931). But in the fungus occurring at Tocklai the spores are distinctly allantoid or botuliform and the cilia are always subterminal. Besides, the spores are unequally divided by a subequatorial septum.

The species *Discosiella cylindrospora* was proposed by Sydow in the year 1912 for a fungus collected by him on old leaves of *Gelonium subglomeratum* from the Palawan Island of the Philippines and the genus *Discosiella* remained monotypic until recently when Batista (1954) and Batista and Lima (1955) have proposed two more species, namely, *D. acrocomia-maculiformis* on *Acrocomia intumescens* and *D. vochysiæ* on *Vochysia oblongifolia*, both occurring on the living leaves



FIGS. 1–6. *Discosiella longiciliata* Agnihothrudu. Fig. 1. Dead tea twig bearing the fructifications (on the patch marked by arrows). Fig. 2. The pycnidium, surface view. 3. The subcuticular pycnidia in section. Fig. 4. Conidiophores and Conidia. Fig. 5. The radiate scutellum of the pycnidium. Fig. 6. Spores. (All the figures are drawn from the type Mycol. Herb. T.E.S. No. 1).

of their respective hosts in the Province of Pernambuco, Brazil (S. America).

Discosiella cylindrospora Sydow (*loc. cit.*) produces small irregular, indeterminate spots that are 3 to 10 mm. broad, the pycnidia lack superficial mycelium, they are dimidiate, 175 to 250 μ and open by an irregular slit, sporophores short, conidia cylindric, obtuse at either end, medianly 1-septate and non-constricted at the septum, 12 to 15 μ by 2·2 to 5·0 μ. The setæ are hyaline, flexuous to falcate, 8 to 10 μ by 1 to 1·5 μ.

D. acrocomia-maculiformis Batista (*loc. cit.*) forms spots that are initially cream-coloured, becoming grey and unlike *D. cylindrospora* are up to 10 mm. broad and many cm. long. The pycnidia are globose depressed and 150 to 305 μ in diameter, completely superficial, with conidiophores that are short and hyaline. Conidia are straight, 1-septate and are much longer than in any of the described species, measuring 19·5 to 27·5 μ by 7·0 to 8·5 μ.

The nature of spots produced by *D. vochysiæ* Batista and Lima (*loc. cit.*) is not described by its authors. The pycnidia are subcuticular as in the previous species but they are either astomate or ostiolate, measuring 180 to 220 μ. Conidiophores are extremely reduced, conidia fusoid, 1-septate, non-constricted 11·5 to 23 μ by 3·5 to 4 μ. The cilia are at the extremities and are much reduced in this species, being 1·5 to 7·5 μ.

The species found on tea bushes at Tocklai, unlike the rest of the species produces the fructifications on twigs and the spots are ill-defined. The pycnidia as in the rest of the species are subcuticular, subiculate but much larger than any of them (200 to 450 μ). They are astomate and dehisce by an irregular rupture. Conidiophores are distinct, but the conidia are different from the other described species in being subcylindric, broad above and somewhat narrow below, allantoid or botuliform, 1-septate subequatorially measuring 16 to 21 μ by 3·6 to 6·4 μ. Spores are 1-ciliate at either extremity, cilia hyaline, flexuous, subterminal and 16 to 28 μ. The cilia are much longer than in any of the already described species.

Since the fungus occurring at Tocklai differs from all the three described species of *Discosiella* in size of the pycnidium, shape of the spore, attachment of the conidial cilia and their length, a new species, namely, *Discosiella longiciliata* is proposed, the name being suggestive of the long cilia characteristic of the species.

Discosiella longiciliata Agnihothrudu sp. nov.

Maculæ in ramulis non bene definitæ; mycelium superficiale omnino abest; pycnidia immersa, subcuticularia, dimidiata, scutata vel paulo hæmispherica, orbicularia vel subelliptica, diametientia 200 to 450 μ, pallide vel fusce brunnea vel fere nigra, sparse subiculata, membranacea vel subcoriacea, constantia e cellulis polygonalibus, quarum parietes crassi sunt, ad centrum et cellulis elongatis rectan-

gularibus ad peripheriem, non translucida in medio, translucida et sat fimbriata ad margines, astomata vel dehiscentia per rupturam irregularem ad apicem sporas extrudentem; conidiophori breves, erecti, haud ramosi, continui vel basaliter semel septati, magnit. 2 to $3\mu \times 1{\cdot}5$ to $2{\cdot}0\mu$; conidia singulariter et apicaliter conidiophoris insidentia, producta abundanter, subcylindrica apicibus obtusis, paulo angustiora ad basim, sæpe allantoidea vel botuliformia, raro recta, hyalina, levibus parietibus prædita, bicellulata, septo sub medium posito et sporam dividente in duas partes aliquantum inæquales, haud constricta ad septum, magnit. $19{\cdot}2 \times 5{\cdot}2\mu$ (16 to $21\mu \times 3$ to $6{\cdot}4\mu$) ut plurimum $19{\cdot}8 \times 5{\cdot}5\mu$, guttulata, semel ciliata at utrumque apicem, ciliis hyalinis, flexuosis, subterminalibus, magnit. $18{\cdot}5\mu$ (16 to 28μ) ut plurimum 22μ.

Typus lectus in ramulis emortuis *Camellia sinensis* (L.) O. Küntze in agellis experimentalibus Stationis Experimentalis Tocklai, in loco Cinnamara, in statu Assamia, a V. Agnihothrudu die 1 Novembris anni 1956 et positus Herbario Mycologico Stationis Experimentalis Tocklai sub numero 1.

Discosiella longiciliata Agnihothrudu sp. nov.

Spots on the twigs ill-defined; superficial mycelium totally absent; pycnidia immersed, subcuticular, scattered, dimidiate, scutate to slightly hemispherical, orbicular to subelliptic, measuring from 200 to 450μ in diameter, pale to dark brown or almost black in colour, sparsely subiculate, membranaceous to subcoriaceous in texture, composed of thick-walled polygonal cells towards the centre and elongate rectangular cells towards the periphery, opaque in the middle, transluscent and rather fimbriate at the margin, astomate and dehiscing by an irregular slit on the top extruding the spores; pycnidia seated on little developed subiculum; conidiophores present, short, erect, unbranched, continuous or basally one-septate, measuring from 2 to 3μ by $1{\cdot}5$ to $2{\cdot}0\mu$; conidia borne singly, apically on the conidiophores, produced abundantly, subcylindrical with obtuse ends, slightly narrower at the base often allantoid or botuliform, rarely straight, hyaline, smooth-walled, two-celled with the septum placed subequatorially, dividing the spore into two somewhat unequal halves, non-constricted at the septum, measuring on average $19{\cdot}2$ by $5{\cdot}2\mu$ (range: 16 to 21μ by 3 to $6{\cdot}4\mu$) and mostly $19{\cdot}8$ by $5{\cdot}5\mu$, guttulate, one-ciliate at either end, cilia hyaline, flexuous, subterminal, measuring on average $18{\cdot}8\mu$ (range: 16 to 28μ) and mostly 22μ.

On dead twigs of *Camellia sinensis* (L.) O. Küntze from the experimental plots of Tocklai Experimental Station, Cinnamara, State of Assam, collected by V. Agnihothrudu on 1st of November 1956. Type deposited in the Mycological Herbarium, Tocklai Experimental Station No. 1.

ACKNOWLEDGEMENTS

I am much thankful to the Director, Tocklai Experimental Station, for permitting me to publish this paper and to Mr. K. C.

Sarmah, the Mycologist for his continued encouragement. I also wish to record my sincere gratitude to Prof. Dr. T. S. Sadasivan, Director, University Botany Laboratory, Madras and to Dr. C. V. Subramanian, Reader in Botany, University of Madras, for critically reading through the manuscript and for their valuable suggestions, to Rev. Fr. Prof. H. Santapau S. J. of St. Xavier's College, Bombay for kindly rendering the Latin diagnosis, to Prof. Dr. A. C. Batista, Director, Institute of Mycology, University of Recife, Pernambuco and to Prof. Dr. M. C. Das, Principal, The Assam Agricultural College, for making available the relevant literature during the course of study of the fungus.

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HYPHOMYCETES—V

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(Received for publication on February 26, 1958)

56. **Endosporostilbe nilagirica** gen. et sp. nov.

This fungus was collected by me during a recent visit to the Nilgiris; it was found growing on dead stems amongst litter in the Government Garden, Ootacamund. The fungus forms conspicuous, scattered synnemata on the substratum. Under a hand lens, each synnema is found to consist of a stout stalk with a capitate expanded and swollen head at its tip. This swollen portion encloses a columella-like darkened portion. The synnemata are 1120–1260 μ tall (inclusive of head). The stalk (stipe) is subcylindrical, broader at base, erect, straight, 840–1080 μ tall, 266–378 μ wide at the base, 168–224 μ wide in the middle and 140–224 μ wide towards the tip, *i.e.*, just below the capitate head. The hyphæ of the synnema are subhyaline, thin, filamentous, simple, septate, 1–2 μ wide and closely clustered together. These hyphæ gradually increase in diameter, become darker brown in colour and towards their tips become free and expand to collectively form the dark coloured columella-like part of the head. The free terminal parts of the hyphæ of the synnemata are the conidiophores. The conidia are produced endogenously and in basipetal succession from within the upper parts of the conidiophores just as in *Thielaviopsis* and are extruded through the open ends of the conidiophores. The conidiophores are 2·8–4·2 μ wide at their tips. The conidia are hyaline, one-celled, rectangular, smooth, thin-walled, 4·2–5·6 μ long and 2·8–3·5 μ wide. Successively produced conidia remain together in chains and an abundance of conidia are produced successively from the same conidiophore. Profuse production of spores from the numerous conidiophore tips forming the head of the synnema results in accumulation of these slimy spores all over the head and thus a mature head of a synnema shows a basal dark columella-like part composed of the dark-coloured free fertile ends of the hyphæ of the synnema, surrounded by a thick, hyaline mass of slimy spores. The columella-like part is 140–200 μ tall and 210–450 μ wide; the slimy mass of spores is often 112–224 μ thick. The head as a whole (*i.e.*, conidiophores + mass of conidia) is 252–420 μ tall and 448–672 μ wide.

The noteworthy features of the fungus are: (*i*) its one-celled endogenous conidia extruded in basipetal succession through the open ends of the conidiophores; and (*ii*) the aggregation of the hyphæ to form distinct synnemata, each with a stalk and a fertile head. The fungus appeared to key down to the genus *Stilbochalara* Ferd. & Winge (Clements & Shear, 1931, p. 229; Saccardo, 1913, p. 1449). The type

specimen of this taxon, however, has been shown to be a *Thielaviopsis* fide Ainsworth & Bisby (1954, p. 345). This name, therefore, is not available for the fungus described here which, as may be seen from the

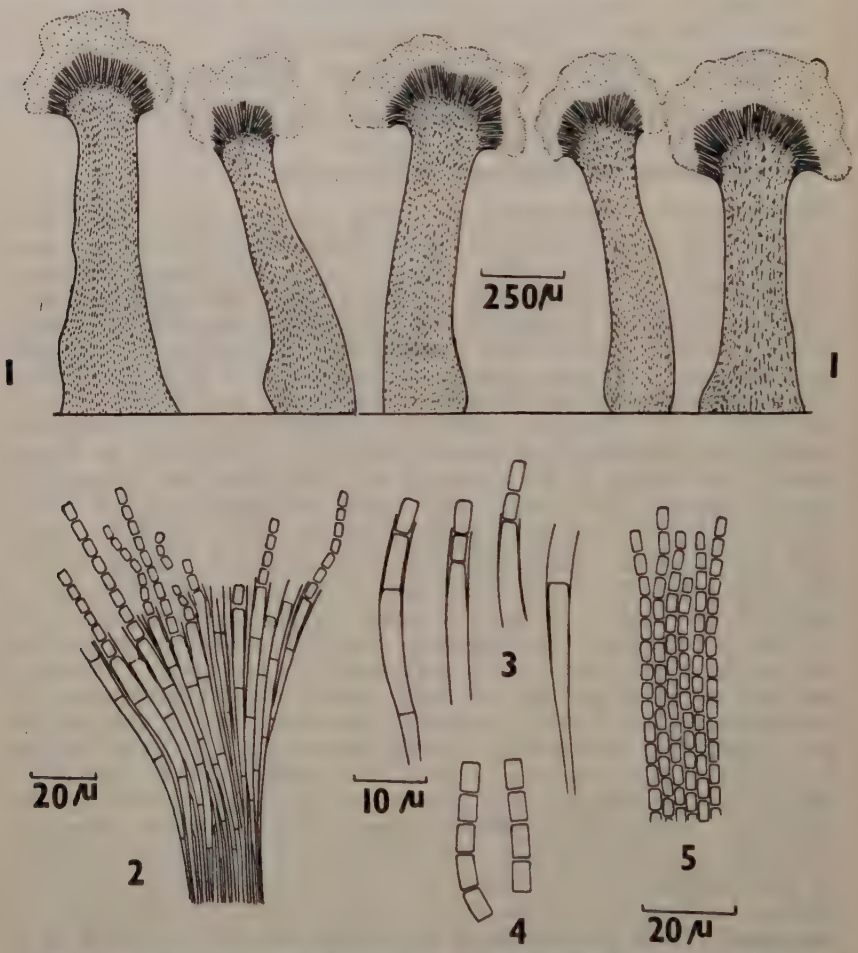

FIG. A. *Endosporostilbe nilagirica* from type specimen, Herb. M.U.B.L. 1926. 1, synnemata; 2, a part of the fertile head of a synnema showing the fertile part of conidiophores (free ends of the hyphæ of the synnema) and conidia; 3, tips of conidiophores showing extrusion of endogenous amerospores in basipetal succession; 4, parts of chains of successively produced spores; 5, a part of accumulated mass of chains of spores.

accompanying description and illustrations, produces distinct synnemata. No other genus of the Stilbaceæ known to me can possibly take in this fungus. Accordingly, it is being classified here in a new genus. The generic name, *Endosporostilbe*, is suggestive of the fact that the fungus belongs to the Stilbaceæ and produces endogenous conidia.

Endosporostilbe Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Phæostilbeas, Amerosporas.

Synnemata simplicia, ornata stipite et capitulo fertili. Stipes constans hyphis simplicibus, septatis, parallelis. Conidiophori (apices liberi hypharum synnematis) divergentes, crassis parietibus præditi, brunnei, fertiles ad apices. Conidia semel cellulata, producta endogene, extrussa successione basipetali per apices apertos conidiophororum.

Fungus imperfectus, Moniliales, Phæostilbeæ, Amerosporæ.

Synnemata simple, with a stalk and fertile head. Stalk composed of simple, septate, parallel hyphæ. Conidiophores (free ends of hyphæ of synnema) diverging, thick-walled, brown, fertile towards the tip. Conidia one-celled, produced endogenously, extruded in basipetal succession through the open ends of conidiophores.

Type species:

Endosporostilbe nilagirica Subramanian sp. nov.

Synnemata conspicua, dispersa, singula ornata stipite robusto atque capitulo distincto, tumido, 1120–1250 μ alta (capitulo incluso). Stipes subcylindricus, erectus, rectus, 840–1080 μ altus, 266–378 μ latus ad basin, 168–224 μ latus ad medium, 140–224 μ latus sub ipso capitulo, constans e hyphis arcte aggregatis, parallelisque. Synnematis hyphæ subhyalinæ, tenues, filiformes, simplices, septatæ, 1–2 μ latæ, gradatim latiores evadentes ubi separantur ad efformanda capitula fertilia. Capitula ornata parte columellæ simili constanti e conidiophoris fuscis (apicibus liberis synnematis), circumdata serie crassa hyalinaque massæ sporarum persistentium; pars similis columellæ 140–200 μ alta, 210–450 μ lata; capitulum integrum (columella et sporarum massa) 252–420 μ alta, 448–672 μ lata; sporarum massa sæpe 112–224 μ crassa. Conidiophori pallide vel fusce brunnei, crassis parietibus præditi, simplices, aperti ad apicem (apice 2·8–4·2 μ lato), fertiles ad apices, producentes conidia endogene. Conidia hyalina, semel cellulata, rectangularia, levia, tenuibus parietibus prædita, 4·2–5·6 μ longa, 2·8–3·5 μ lata, endogena, limosa, extrussa successione basipetali per apices apertos conidiophororum, sæpe catenulata post extrussionem atque efformantia massas persistentes super partem fertilem capitatam synnematis.

Typus lectus in culmis emortuis, in hortu gubernii, ad Ootacamund, in regione Nilgiris, in Statu Madras, die 23 novembris anni 1957 a C.V.S. et positus in herbario M.U.B.L. sub numero 1926.

57. **Deightoniella indica** sp. nov.

This fungus was also collected on dead stems from the Government Garden, Ootacamund. The colonies are brown and effuse. The repent hyphæ are subhyaline to pale or golden brown in colour, slender, septate and branched. The conidiophores are short and arise

laterally or terminally from cells of repent hyphæ. Each conidiophore consists of an elongate basal cell and a septate torulose upper part composed of 1–5, usually 1–3, globose or subglobose cells. The apical cell of the torulose chain is sporogenous and bears acrogenously a single conidium. Sometimes more than one conidium may be produced on a sporogenous cell, but from different points on it. Branching of conidiophores is common. The branches are usually 1–4-celled and are again torulose and similar to the torulose part of simple conidiophores. The branches may arise from the apical part of the basal cell of the conidiophore or from one of the cells of the torulose upper part of the main conidiophore. Secondary branches, similar to the primary branches, may arise in the same way on primary branches. In each case, the apical cell of the main conidiophore or branches is sporogenous and may be distinguished from the other cells of the conidiophore by its thicker wall and darker colour except towards the point of origin of a conidium where it is paler in colour. The conidiophores are 14–25 μ long, 3–7 μ wide at the point of origin and 5·4–9·0 μ wide at the swollen parts of the torulose portion. The conidia are produced singly. The mature conidia are long, brown in colour, up to 30-septate, torulose and markedly constricted at septa, with cells widest in the middle part (and narrower towards either end), with a prominent scar on the basal cell indicating point of attachment to conidiophore, distinctly and markedly verrucose to tuberculate, golden brown in colour when young, straight, sometimes bent or curved, and 60–200 μ long; the basal and apical cells are 7·0–7·7 μ wide, the middle cells 8–17 μ wide. The individual cells of the conidia are seldom more than 18 μ long.

The conidia are phragmospores produced singly and each conidium bears only one scar on the basal cell indicating point of attachment to the conidiophore. Despite careful search, no conidium with scars at both ends have been seen and this shows that the conidia are not catenate. The development of the conidium is interesting. A hyaline swelling arises at the tip of the sporogenous cell; this swelling becomes globose, golden brown in colour and minutely verrucose. A second swelling arises at the tip of the first one, later a third one at the tip of the second; this process is repeated many times and thus a multiseptate, torulose conidium constricted at septa and of variable length is produced. Usually only one conidium per sporogenous cell is produced after which the conidiophore proliferates, but rarely two may be produced per sporogenous cell. The conidia are deciduous and I have seen mature conidia attached to the conidiophore only in a few cases. However, many young conidia still in the process of development have been seen. After one conidium is shed, the conidiophore proliferates through the scar of the fallen conidium and produces a series of 1–3 globose to subglobose cells constricted at septa, of which the apical one usually becomes sporogenous and produces one or more conidia singly at the apex. This process of conidiophore proliferation and conidial production may be repeated several times. In all cases the apical sporogenous cell of each new proliferation of

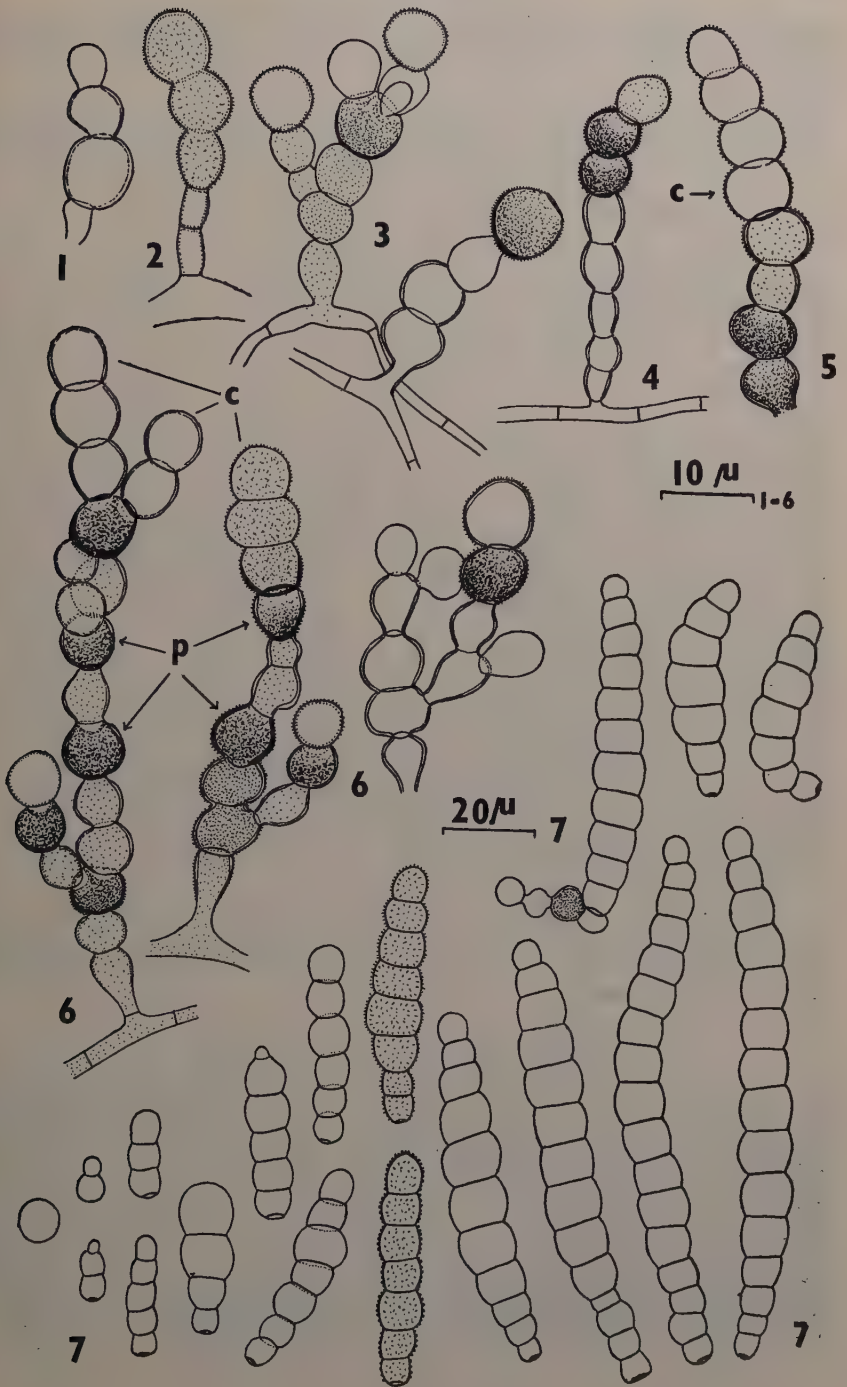

FIG. B—1-7

FIG. B. *Deightoniella indica* from type specimen, Herb. M.U.B.L. 1925. 1–6, progressive stages in the development of conidiophores and conidia; 7, mature conidia and conidia in various stages of development. *c* = conidium; *p* = sporogenous cell.

the conidiophore can be distinguished by its darker colour and thicker wall except, as already mentioned, towards the point of origin of conidia.

The noteworthy features of the fungus just described are, of course, the repeated proliferation of the conidiophore through the sporogenous cells after the spores are shed and the successive production of sporogenous cells and conidia following renewed conidiophore growth each time this process takes place. The conidia are phragmospores and only one spore is usually produced on a sporogenous cell. The conidia are produced singly and not in chains. These are features characteristic of *Deightoniella africana* Hughes, the type species of the genus *Deightoniella* Hughes (Hughes, 1952, pp. 27–29). In *D. africana* the conidiophores are short, simple and torulose; after the first conidium is shed, the conidiophore grows out through the scar of the fallen conidium and immediately produces another spore; this process is repeated. Notwithstanding these similarities, in the fungus I have just described, the characteristic sporogenous cells are not always produced in succession to form chains as in *D. africana*, but are usually separated by one or two thinner-walled and paler coloured intercalary cells. Moreover, the conidiophore may become branched and this often happens in the following way. After a conidium is shed, the conidiophore may proliferate from two points on the sporogenous cell and each of these proliferations may immediately produce a sporogenous cell or a chain of cells of which the apical one becomes a sporogenous cell. These are features not found in *D. africana*. Nevertheless, considering the fact that both fungi produce phragmospores singly on conidiophores capable of successive proliferation and fruiting, I consider that my fungus may be provisionally classified in the genus *Deightoniella*.

My fungus very clearly differs from taxa classified in this genus so far (*see* Ellis, 1957); its distinctive torulose multiseptate conidia are the longest known for the genus. It is, therefore, being classified here as a new species.

Deightoniella indica Subramanian sp. nov.

Coloniæ brunneæ effusæ. Hyphæ repentes subhyalinæ vel pallide vel auree brunneæ, tenues, septatæ, ramosæ. Conidiophori breves, simplices vel ramosi, surgentes lateraliter vel terminaliter e cellulis hypharum repentium, constantes e cellula basali elongata, atque parte superiore torulosa septata 1–5 (ut plurimum 1–3) cellularum globosarum vel subglobosarum, ut plurimum 14–25 μ longi, 3–7 μ lati ad basin, 5·4–9·0 μ lati ad partem tumidam partis torulosæ; cellula apicalis conidiophori crassioribus atque fuscioribus parietibus prædita quam cæteræ cellulæ, sporogena, suffulciens conidium unicum acrogene vel raro conidia duo e punctis diversis circum apicem. Conidiophori

proliferantes successive per cicatrices conidiorum effusorum atque producentes immediate cellulam sporogenam (et conidia) vel seriem cellularum 1–3 subglobosarum vel globosarum desinentium in cellulam sporogenam (et conidia). Conidia matura longa, brunnea, usque 30–septata, torulosa et distincte constricta ad septa, cellulis latioribus ad medium, verrucosa vel tuberculata, recta vel curva, cicatrice prominente in cellula basali monstrante punctum junctionis cellulæ sporogenæ, 60–200 μ longa, producta singulariter; cellulæ basales et apicales 7·0–7·7 μ latæ; cellulæ mediæ 8–17 μ latæ.

Typus lectus in culmo emortuo in hortu gubernii, ad Ootacamund, in regione Nilgiris, in Statu Madras die 23 novembris anni 1957 a C.V.S. et positus in Herb. M.U.B.L. sub numero 1925.

58. **Dwayabeeja sundara** gen. et sp. nov.

This fungus was collected on dead leaf rachis of *Phœnix canariensis* from the Sim's Park, Coonoor. The fungus forms powdery, blackish-brown, effuse colonies on the substratum. The vegetative hyphæ are thin, subhyaline, smooth, branched, septate and 1–3 μ wide. The conidia are produced on distinct and characteristic sporogenous cells. The sporogenous cells may be produced directly on simple outgrowths from cells of the repent hyphæ or on conidiophores. The conidiophores are short and arise laterally or terminally from cells of the repent hyphæ. The conidiophores may be simple and one-septate, consisting only of one somewhat elongate basal cell and a single apical sporogenous cell (rarely, instead of one apical sporogenous cell, two may be formed side by side); or they may be torulose and composed of a series of subglobose to irregularly shaped cells of which the terminal one alone is sporogenous. Sometimes the conidiophores are branched. The cells of the conidiophore are 4·9–5·6 μ long and wide, smooth, and pale-brown or brown in colour. The sporogenous cell usually occurs singly; it is darker in colour and thicker-walled than other conidiophore cells, is roughened, subglobose to globose, 5·6–7·7 μ tall and 6·3–7·7 μ wide. When the conidia are shed, the sporogenous cells, with their apical parts torn off, often take on a cupulate appearance.

Two different types of conidia may be produced on one and the same sporogenous cell: phragmospores and scolecospores. The phragmospores are dark brown in colour, elongate-fusiform, torulose, straight or curved, many-(up to 12)-septate, slightly or sometimes markedly constricted at the septa, usually broadest in the middle but sometimes above or below the middle portion, with a smoothly rounded apical cell and a somewhat similar basal cell with a scar showing the point of attachment to the sporogenous cell. The middle cells of the conidia are verrucose and roughened; they are darker in colour than the cells towards either end and are also thicker walled. The conidia are 32–66 μ long, 8·4–11·2 μ where they are widest; the basal cell is 2·8–5·6 μ long and 5·6–6·3 μ wide. One to three such phragmospores may be produced singly (not in chains) from different points on a sporogenous cell. The scolecospores are brown in colour, slightly paler

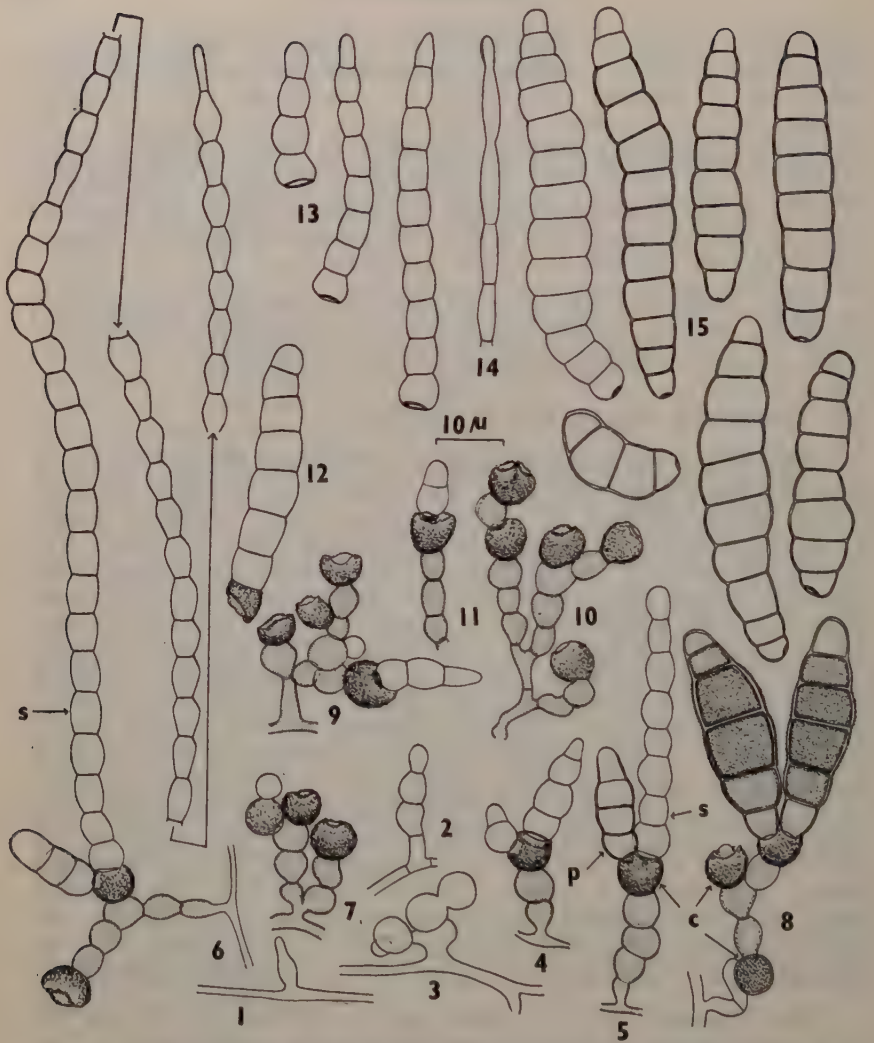

FIG. C. *Dwayabeeja sundara* from type specimen, Herb. M.U.B.L. 1924. 1–11, progressive stages in the development of conidiophores and conidia; 12, a phragmospore torn off from a sporogenous cell—note part of the sporogenous cell remaining attached to the base of the spore; 13, young scolecospores; 14, apical part of a scolecospore; 15, phragmospores. *c* = sporogenous cell; *p* = phragmospore; *s* = scolecospore.

than the phragmospores, very long, whip-like, straight or flexuous, many-septate, thin and filamentous towards the tip, darker below, paler above, and almost hyaline towards the tip. Each scolecospore has a distinct and characteristic basal cell which is broadest at the base and has a clear scar at the base. The spores are distinctly constricted at the septa. The cells towards the base are shorter than those above;

the former are barrel-shaped, the latter are long-fusiform. The cells towards the base are thick-walled and roughened; those above are progressively thin-walled and subhyaline to hyaline. The basal cell is 4·2–5·6 μ long and 5·6–7·0 μ wide. The middle cells are 7·0 × 4·9 μ, the cells towards the apex are 8·4–11·2 × 2·8 μ, and the apical cell is usually 5·6–8·4 × 2·8 μ. When young, these spores are short and few-septate, but mature scolecospores are usually 180–420 μ long and the longer spores are usually 35–50-septate.

Both types of conidia, *viz.*, phragmospores and scolecospores, may be formed on one and the same sporogenous cell and one or more of each of these two types, or only one, may be produced on a sporogenous cell. However, even in the young stages the scolecospore can be distinguished from the phragmospore by the characteristic basal cell of the former. Both types of spore arise as buds from the sporogenous cell. The phragmospore is formed in the usual way. The scolecospore develops by progressive elongation and progressive septation from the base to the apex. In a developing scolecospore some apical septa may be absent, but with progressive elongation of the spore, these septa appear. At first sight I had thought what I have designated here as scolecospores to be merely septate sterile appendages; but since each of these has a distinct basal scar and is deciduous, it is proper to consider them spores. When conidia formed on a sporogenous cell are shed, conidiophore growth is resumed through the torn apex of the sporogenous cell, or often from one or more points or through scars of fallen conidia on the sporogenous cells. The renewed conidiophore growth may consist of a pale coloured or subhyaline basal cell and an apical sporogenous cell, or may consist of a row of such cells with an apical sporogenous cell. Conidia are then produced on these new sporogenous cells and this process may be repeated.

The noteworthy features of this fungus are: (*i*) the two types of conidia, *viz.*, phragmospores and scolecospores, which are always produced singly (not in chains) and may be produced on one and the same sporogenous cell; (*ii*) the peculiar method of conidial formation on characteristic sporogenous cells and successive repetitions of growth of conidiophore by proliferations through scars of previous conidia or torn apices of sporogenous cells followed by conidial formation on the freshly produced sporogenous cells. The phragmospore often gets torn from the sporogenous cell and in such cases the spore has the torn apical part of the sporogenous cell attached to its base. This is a feature reminiscent of *Torula herbarum*, the type species of the genus *Torula*. The torulose conidiophores also very much resemble those of *Torula herbarum*. However, unlike *T. herbarum*, two types of conidia (*i.e.*, phragmospores and scolecospores) are produced by my fungus, both of which are formed singly and not in chains. The conidia of *T. herbarum* are phragmospores formed in acropetal chains. No doubt, spore formation in the fungus just described is very similar to what is seen in *Deightoniella indica* described elsewhere in this paper, but *D. indica* produces only phragmospores but no scolecospores.

In producing the phragmospores singly and not in chains, the fungus under study differs also from the genus *Pseudotorula* described later in this paper. I know of no genus which combines the features of my fungus and it is therefore being classified here in a new genus. The generic and specific names chosen are both derived from Sanskrit: the generic name *Dwayabeeja* from द्वय (dwaya) = of two kinds, and बीज (beeja) = seed, indicative of the two types of conidia produced by the fungus; the specific epithet *sundara* from सुंदर (sundara) = beautiful.

Dwayabeeja Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Dematiaceas, Phragmosporo-Scolecosporas.

Hyphæ repentes septatæ, ramosæ. Conidiophori surgentes lateraliter vel terminaliter e cellulis hypharum repentium, simplices vel ramosi, septati, producentes conidia singulariter e cellulis sporogenis distinctis, sæpe proliferantes per cicatrices (conidiorum deciduorum) e cellulis sporogenis atque producentes cellulas sporogenas et conidia iterum atque iterum. Conidia duplicia: phragmosporæ et scolecosporæ, producta singulariter (haud catenate) e cellulis sporogenis. Phragmosporæ brunneæ. Scolecosporæ longæ, septatæ, brunneæ.

Accedit ad *Pseudotorulam* eo quod producit conidia duplicia, differt tamen eo quod producit phragmosporas singulariter nec catenulate.

Fungus imperfectus, Moniliales, Dematiaceæ, Phragmosporæ-Scolecosporæ.

Repent hyphæ septate, branched. Conidiophores arising laterally or terminally from cells of repent hyphæ, simple or branched, septate, producing conidia singly on distinct sporogenous cells, often proliferating through scars (of fallen conidia) on sporogenous cells and producing sporogenous cells and conidia repeatedly. Conidia of two types: phragmospores and scolecospores, produced singly (not in chains) on sporogenous cells. Phragmospores brown. Scolecospores long, septate, brown.

Resembling *Pseudotorula* in producing two types of conidia, but differing from it in producing phragmospores singly and not in chains.

Type species:

Dwayabeeja sundara Subramanian sp. nov.

Coloniæ effusæ, pulverulentæ, nigrescenti-brunneæ. Hyphæ tenuibus parietibus præditæ, subhyalinæ, leves, ramosæ, septatæ, 1–3 μ latæ. Conidiophori surgentes lateraliter vel terminaliter e cellulis hypharum repentium, breves et 0–4-septati in juvenili conditions, cum septati tum torulosi, longiores et pluries septati ad maturitatem, desinentes in cellulam sporogenam (raro in duas cellulas sporogenas

parallelas). Conidiophororum cellulæ pallide brunneæ, leves, formæ variæ, 4·9–5·6 μ longæ et latæ; cellulæ sporogenæ fusce brunneæ, crassis parietibus præditæ, verrucosæ, subglobosæ vel globosæ, sæpe cupulatæ post effusionem conidiorum, producentes unum vel plura conidia singulariter ad apicem, 5·6–7·7 μ altæ, 6·3–7·7 μ latæ. Conidiophori proliferantes per cicatrices conidiorum effusorum e cellulis sporogenis et producentes cellulas sporogenas atque conidia successive. Conidia producta singulariter (haud catenulate) e cellulis sporogenis. Conidia duplicia: phragmosporæ et scolecosporæ. Phragmosporæ fusce brunneæ, elongato-fusiformes, torulosæ, rectæ vel curvæ, pluries (usque duodecies) septatæ, tenuiter vel clare constrictæ ad septa, ut plurimum latissimæ ad medium (nonnumquam supra vel infra partem mediam), cellula apicali rotundata atque cellula basali simili ornata cicatrice basali. Cellulæ mediæ phragmosporarum verrucosæ et asperæ, fusciores atque crassioribus parietibus ornatæ quam cellulæ apicales. Phragmosporæ 32–66 μ longæ, 8·4–11·2 μ ad partem latiorem; cellula basalis 2·8–5·6 μ longa, 5·6–6·3 μ lata. Scolecosporæ brunneæ, paulo pallidiores phragmosporis, longissimæ, funiculo similes, rectæ vel flexuosæ, pluries septatæ, 180–420 μ longæ ad maturitatem, ad apicem tenues, filiformes et pallidiores, ad basin crassis parietibus præditæ, asperæ et fusciores. Cellula basalis scolecosporarum 4·2–5·6 μ longa, 5·6–7·0 μ lata; cellulæ mediæ 7·0 × 4·9 μ; cellulæ ad apicem 8·4–11·2 × 2·8 μ.

Typus lectus in rachide foliorum emortuorum *Phœnicis canariensis* Chabaud, ad Sim's Park, in loco Coonoor, in regione Nilgiris, in Statu Madras, die 22 novembris anni 1957 a C.V.S. et positus in Herb. M.U.B.L. sub numero 1924.

59. **Pseudotorula heteiospora** gen. et sp. nov.

This fungus was collected by me on dead stems from the Government Garden, Ootacamund (Nilgiris). The fungus forms blackish, powdery, effuse colonies on the substratum. The repent hyphæ are subhyaline to pale brown, slender, septate, branched and 2–5 μ wide. The conidiophores arise laterally or terminally from cells of the repent hyphæ, and are usually short, simple, subhyaline to brown, septate, and constricted at septa. Each conidiophore has a characteristic apical sporogenous cell. The basal cell of the conidiophore is somewhat elongate-clavate, 7–10 μ long and 4·2–5·6 μ wide at the tip; the other cells of the conidiophore are subglobose to globose or irregular in shape and are seldom more than 7·0 μ in diameter. The sporogenous cells may be produced either on conidiophores or on simple lateral protuberances on the repent hyphæ. The sporogenous cells are subglobose to globose, thick-walled, roughened, dark brown in colour, and can be easily distinguished from other cells by these features; when they are mature and when the conidia are shed, they appear considerably thickened and darkened all over except towards the apex and present a cupulate appearance; they are 5·6–7·0 (rarely up to 8·4) μ in diameter. Two types of conidia are produced on the sporogenous cells, often together: (*i*) phragmospores in chains and (*ii*) scolecospores

singly. Each sporogenous cell produces 1–3 phragmospore chain initials and usually not more than one scolecospore. The phragmospores are produced in simple or branched acropetal chains as in the case of *Torula herbarum*. In the phragmospore chain, up to four conidia may be produced from the apical cell of a conidium. The phragmospores are dark brown in colour, elliptical to oval, 2–5 (mostly 3-) septate, constricted at one or more septa, thick-walled, 11–24 μ long and 5·6–7·0 μ wide. The scolecospores are usually produced singly along with phragmospore chains on a sporogenous cell; sometimes they may be produced singly from the tip of a conidium in a phragmospore chain. Thus, scolecospores may arise from a sporogenous cell of a conidiophore or an apical cell of a phragmospore which in this fungus is a potential sporogenous cell, although normally an apical cell of a phragmospore gives rise only to phragmospore initials or phragmospore chain initials. The scolecospores are long, whip-like, brown, darker below, paler above, finely verrucose, many-septate, often constricted at septa, erect, straight or flexuous, 125–450 μ long, 4–6 μ wide in the middle and 2·8–3·5 (– 4·2) μ wide at the tip. The basal cell is up to 5·6 μ long and 7·0 μ wide and has a clear basal scar. The scolecospore cells are 4·2–7·0 (– 8·4) μ long. The apical cell is smoothly rounded at the tip.

The sporogenous cells and the phragmospore chains of this fungus bear a very close resemblance to those of *Torula herbarum*, the type species of the genus *Torula*. However, production of scolecospores is a feature not shared by *T. herbarum*. Compared to the number of phragmospores produced on each sporogenous cell, the number of scolecospores formed are few, but what is noteworthy is their presence. The basal scar showing the point of attachment to the sporogenous cell and the fact that these scolecospores are also often produced on apical (potentially sporogenous) cells of a conidium in a phragmospore chain, indicate that they may be considered spores. Proliferation of conidiophore through a sporogenous cell after the conidia are shed may take place as in *Deightoniella indica*, but this is rare. There is no doubt that the function of repeated conidiophore proliferation is fulfilled in this case by the potential ability of apical cells of the phragmospores to function as sporogenous cells. Such ability is not shared by the scolecospores. The fungus just described no doubt resembles the genus *Dwayabeeja* proposed elsewhere in this paper in forming two types of spores, but in contrast to *Dwayabeeja* the phragmospores in this fungus are produced in chains and not singly. I know of no genus in which this fungus can be suitably accommodated and I therefore propose a new genus for it. The name chosen, *viz.*, *Pseudotorula*, is suggestive of the superficial resemblance to *Torula*; the specific epithet *heterospora* is further suggestive of the two types of spores produced.

Pseudotorula Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Dematiaceas, Phragmosporo-Scolecosporas.

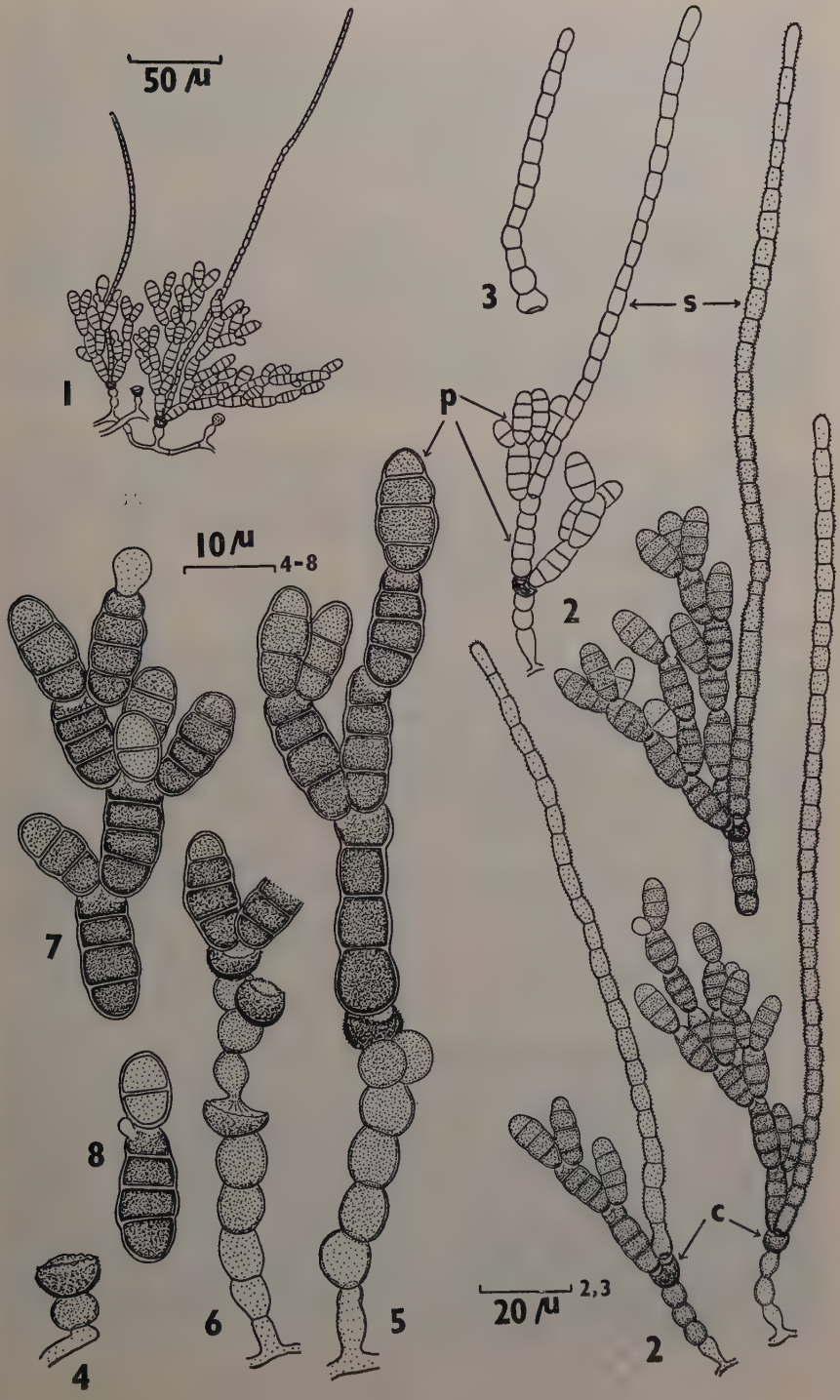

FIG. D—1–8

FIG. D. *Pseudotorula heterospora* from type specimen, Herb. M.U.B.L. 1922. 1, fungus showing repent hyphæ, conidiophores, scolecospores and chains of phragmospores; 2, conidiophores bearing scolecospores and branched acropetal chains of phragmospores. Note the production of scolecospores singly on sporogenous cells and also on the apical cell of a phragmospore; 3, a young scolecospore; 4, a simple conidiophore with a (cupulate) sporogenous cell which has shed the spores; 5–8, stages in the development of phragmospores. *c* = sporogenous cell; *p* = phragmospore; *s* = scolecospore.

Hyphæ septatæ, ramosæ, brunneæ. Conidiophori surgentes e cellulis hypharum repentium, simplices, semel vel pluries septati, torulosi, singuli ornati cellula apicali sporogena. Conidia duplicis conditionis: phragmosporæ et scolecosporæ, utræque productæ e cellulis sporogenis. Phragmosporæ brunneæ, productæ in catenas tum simplices tum acropetas ramosas. Scolecosporæ longæ, septatæ, productæ singulariter e cellulis sporogenis vel e cellulis apicalibus phragmosporarum.

Accedit ad *Dwayabeejam* eo quod tum phragmosporas tum scolecosporas producit, differt tamen eo quod phragmosporæ producuntur catenulatæ neque singulariter; accedit etiam ad *Torulam* eo quod producit phragmosporas in catenas ramosas acropetas, differt tamen eo quod producit etiam scolecosporas.

Fungus imperfectus, Moniliales, Dematiaceæ, Phragmosporæ-Scolecosporæ.

Hyphæ septate, branched, brown. Conidiophores arising from cells of repent hyphæ, simple, 1- or more-septate, torulose, each with an apical sporogenous cell. Conidia of two types: phragmospores and scolecospores, both produced on sporogenous cells. Phragmospores brown, produced in simple or branched acropetal chains. Scolecospores long, septate, produced singly on sporogenous cells or on apical cells of phragmospores.

Resembling *Dwayabeeja* in producing phragmospores and scolecospores, but differing from it in having phragmospores produced in chains and not singly. Resembling *Torula* in producing phragmospores in branched acropetal chains, but differing from it in producing scolecospores also.

Type species:

Pseudotorula heterospora Subramanian sp. nov.

Coloniæ pulverulentæ, effusæ, nigrescentes. Hyphæ repentes subhyalinæ vel pallide brunneæ, tenues, septatæ, ramosæ, 2–5 μ latæ, producentes conidiophoros lateraliter et terminaliter. Conidiophori breves, ut plurimum simplices, subhyalini vel pallide brunnei, septati, constricti ad septa, desinentes in cellulam sporogenam. Cellulæ sporogenæ insidentes ipsis cellulis hypharum repentium vel conidiophoris, fusce brunneæ, crassis parietibus præditæ, verrucosæ, subglobosæ vel globosæ, 5·6–7·0, raro ad 8·4 μ diam., singulæ producentes 1–4 catenas phragmosporarum et singulas scolecosporas. Cellula basalis conidiophori elongato-clavata, 7–10 μ longa, 4·2–5·6 μ lata

ad apicem; cellulæ cæteræ conidiophori usque ad 7 μ diam. Conidia duplicia: phragmosporæ et scolecosporæ. Phragmosporæ fusce brunneæ, ellipticæ vel ovales, 2–5 (ut plurimum 3-) septatæ, generatim constrictæ ad unum vel plura septa, crassis parietibus præditæ, 11–24 μ longæ, 5·6–7·0 μ latæ, productæ in catenas simplices vel ramosas acropetas. Scolecosporæ productæ singulariter e cellulis sporogenis vel e cellulis apicalibus phragmosporarum, longæ, flagello similes, brunneæ, fusciores infra, minute verrucosæ, pluries septatæ, constrictæ ad septa, erectæ, rectæ vel flexuosæ, 125–450 μ longæ, usque ad 7·0 μ latæ ad basin, 4–6 μ latæ ad medium, 2·8–3·5 (–4·2) μ latæ ad apicem; cellula basalis usque ad 5·6 μ longa, cæteræ cellulæ 4·2–7·0 (–8·4) μ longæ; cellula apicalis leviter rotundata ad apicem.

Typus lectus in culmo emortuo in hortu gubernii ad Ootacamund, in regione Nilgiris, in Statu Madras, die 23 novembris anni 1957 a C.V.S. et positus in Herb. M.U.B.L. sub numero 1922.

60. **Septonema olivaceo-nigrum** Berk. & Br.

Septonema olivaceo-nigrum was described by Berkeley and Broome (1873, p. 90) in Fungi of Ceylon No. 806. Their description of the fungus was as follows: "Pulvinulis tomentosis olivaceo-nigris congestis; sporis 4-articulatis, articulis globosis echinulatis e floccis ramosis articulatis oriundis (No. 248). Apparently on leaves of *Agave*. Spores ·0008 long." Berkeley and Broome illustrated the fungus in their Plate III, Fig. 8 and in the legend to the Plate cited the name as *Septonema olivaceum*, obviously in error. Fifty years later, Petch studied the type and wrote: "This fungus in the type forms lax tufts, about 0·2 mm. in diameter, with a pseudoparenchymatous base. These extend and become confluent in purple-black, effused masses. The hyphæ are brown or black-brown, 4 μ in diameter, regular, rigid, septate, smooth, much branched. The conidia are catenulate, either one-septate, oblong, with rounded ends, strongly constricted at the septum, black-brown, verrucose, 8–11 × 4–5 μ, or three-septate, slightly constricted, sometimes only slightly verrucose, 14–28 × 5 μ" (Petch, 1924, p. 172).

Through the courtesy of Dr. J. W. L. Peiris, Plant Pathologist, Department of Agriculture, Peradeniya, Ceylon, I have been able to examine part of the type material of this fungus. The fungus is in good condition and forms lax tufts with a pseudoparenchymatous base. The colonies are brownish black and effuse. The vegetative hyphæ are pale brown in colour, branched, septate (distance between septa 9–25 μ), 2·8–4·2 μ wide and smooth-walled. The spores are dark brown when mature, thick-walled and distinctly verrucose. They may be non-septate and subglobose to ovate or they may be somewhat elongate, subcylindrical and 1–4 (–5)-septate, slightly or markedly constricted at septa, and 8·4–28·8 × 4·2–5·6 μ. The conidia are arthrospores formed in the same way as in *Geotrichum*, by fragmentation of the mycelium. In contrast to *Geotrichum*, however, the spores in *Septonema olivaceo-nigrum* are largely phragmospores. The

4- and 5-septate conidia may fragment further into 1-3-septate ones. Careful examination of the material shows that conidial fragments formed by intercalary segmentation of mycelium are open at either end; however, the individual cells of the conidium become enclosed

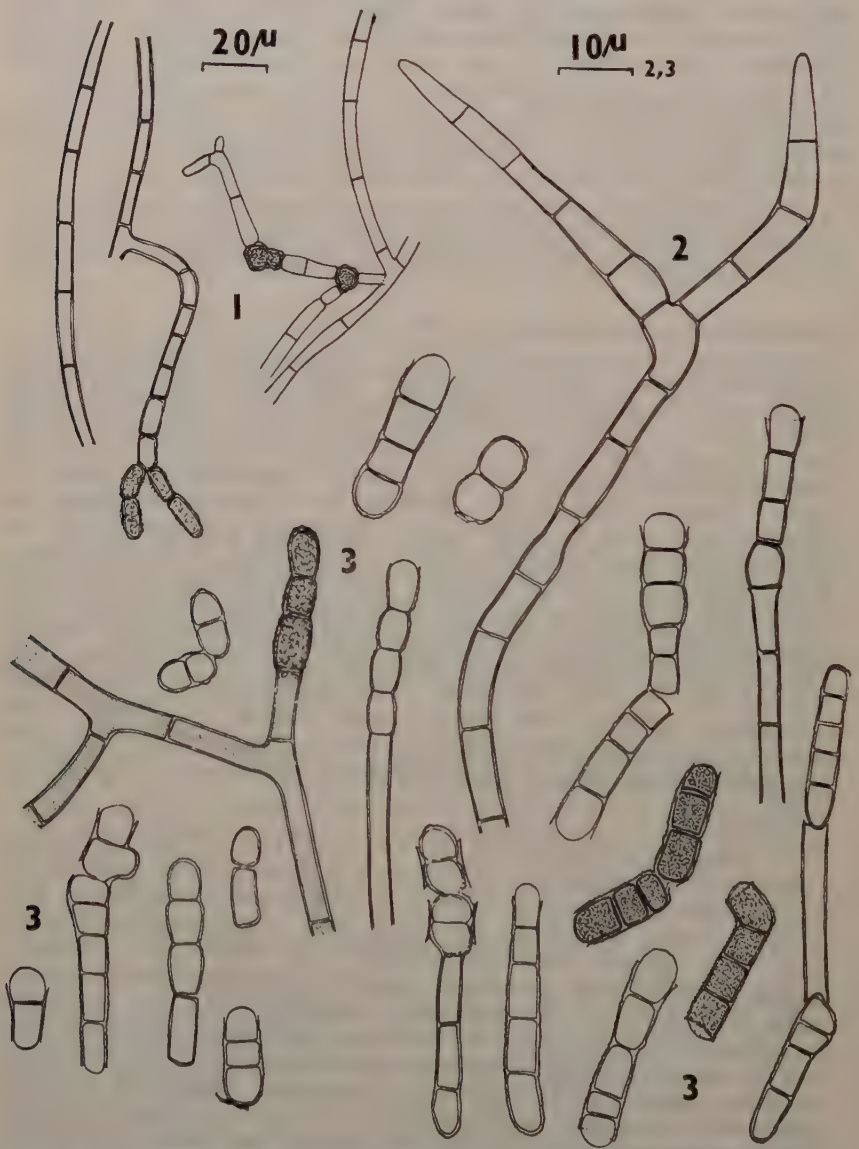

FIG. E. *Bahusakala olivaceo-nigra* from type specimen, Herb. M.U.B.L. 1430. 1, hyphæ with arthrospores; 2, part of septate, branched hypha; 3, arthrospores and their development.

in thick walls and the conidium appears to be endogenous within the cell-wall of the segmented fungus hypha.

I have made two collections of this fungus recently from the Nilgiris, Madras State, one on an unidentified Liliaceous plant and the other on dead *Yucca gloriosa*. Both collections match well with type material of *Septonema olivaceo-nigrum*.

The description and the accompanying figures clearly indicate that the fungus is not a *Septonema*; for, in *S. secedens* Corda which is the type species of this genus the phragmospores are true conidia formed in acropetal chains which may be simple or branched (*see* Hughes, 1951). In *S. olivaceo-nigrum* the spores are arthrospores; whilst it has similarities with *Geotrichum*, it may be distinguished from the latter by its phragmo-arthrospores; in *Geotrichum* the spores are amero-arthrospores. Accordingly, a new genus is being proposed to accommodate *Septonema olivaceo-nigrum*. The generic name *Bahusakala* is derived from Sanskrit: बहु (bahu) = many; and शकल (sakala) = bit, indicative of the fragmentation of the hyphæ into many bits to form arthrospores.

Bahusakala Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Dematiaceas, Phragmosporas. Hyphæ brunneæ, septatæ, ramosæ. Conidia (arthrosporæ) efformata per fractionem intercalarem et terminalem hypharum, ut plurimum semel ad sæpius transverse septata, nonnumquam haud septata.

Fungus imperfectus, Moniliales, Dematiaceæ, Phragmosporæ. Hyphæ brown, septate, branched. Conidia (arthrospores) formed by intercalary and terminal fragmentation of hyphæ, usually one to many times transversely septate, sometimes non-septate.

Type species:

Bahusakala olivaceo-nigra (Berk. & Br.) Subramanian comb. nov.

Basonym.—Septonema olivaceo-nigrum Berk. & Br., in *J. Linn. Soc. Lond. Botany*, 1873, **14**: 90, ic.; Saccardo, 1884, *Sylloge Fungorum*, **4**: 400.

Type specimen.—On leaves of *Agave* (Ceylon), Thwaites 248 ex Herb. Plant Pathologist, Royal Botanic Garden, Peradeniya, Ceylon (Herb. M.U.B.L. No. 1430—slide).

Other collections.—On dead Liliaceæ, Government Garden, Ootacamund, Nilgiris District, Madras State, 24–11–1956, coll. C.V.S. (Herb. M.U.B.L. No. 1747); on *Yucca gloriosa*, Government Garden, Ootacamund, Nilgiris District, Madras State, 24–11–1956, coll. C.V.S. (Herb. M.U.B.L. No. 1750).

This appears to be the first record of this fungus from India.

Summary

In this paper four new and interesting Hyphomycetes are described from collections made from the Nilgiris, Madras State, India. They are: *Deightoniella indica* sp. nov. on dead stems; *Dwayabeeja* gen. nov. (Dematiaceæ, Phragmosporæ-Scolecosporæ) with the type species, *D. sundara* sp. nov., on dead leaf rachis of *Phœnix canariensis*; *Pseudotorula* gen. nov. (Dematiaceæ, Phragmosporæ-Scolecosporæ) with the type species, *P. heterospora* sp. nov., on dead stems; and *Endosporostilbe* gen. nov. (Phæostilbeæ, Amerosporæ) with the type species, *E. nilagirica* sp. nov., also on dead stems. *Septonema olivaceo-nigrum* Berk. & Br. is reported for the first time from India from two collections, also from the Nilgiris; on the basis of a study of type material of this species, it is made the type of a new genus of the Dematiaceæ, *Bahusakala*.

Acknowledgements

I am very grateful to Prof. Dr. H. Santapau of the St. Xavier's College, Bombay, for kindly translating the diagnoses of the new genera and species into Latin. I am also grateful to Dr. J. W. L. Peiris, Plant Pathologist, Department of Agriculture, Peradeniya, Ceylon, for kindly sending me on loan type material of *Septonema olivaceo-nigrum*.

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MORPHOLOGY AND PHYSIOLOGY OF FOUR STRAINS OF YEASTS FROM HUMAN FÆCES AND THEIR *IN VITRO* SENSITIVITY TO NYSTATIN

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(Received for publication on November 8, 1957)

In the course of investigations to standardize the plating method for the quantitative estimation of microbial flora of the human fæces, four strains of yeasts were isolated. In view of the fact that about 15% of normal people harbour *Candida albicans* (Robin) Berkhout, in the intestinal tract (Nickerson, 1953; Skinner, 1947), it was considered of interest to study the morphology and physiology of these yeasts and compare them with *C. albicans*, a known pathogenic yeast-like fungus (Chopra, Mukerji and Chopra, 1954). Preliminary observations on the pathogenicity of these yeasts in laboratory animals and their *in vitro* sensitivity to an antifungal agent, Nystatin have also been made.

Material and Method

The four strains of yeasts (Y_1, Y_2, Y_3 and Y_4) that appeared different in colony character were isolated by the plating technique from fæces of a healthy man on modified standard medium plates (Das Gupta, 1930). The medium had the following composition: glucose 2·0 g., potassium nitrate 2·0 g., magnesium sulphate 0·7g., neutral potassium phosphate 1·25 g., amylum 10·0 g., agar 30·0 g., and distilled water 1,000 ml. The pH was adjusted to approximately 3·5 by adding a 10% sterile solution of tartaric acid at the time of plating. The yeasts were purified by plating on Sabouraud's destrose agar (SDA) at 25–27 ° C. They were maintained on SDA slants and kept at 4° C. when not in use. Subcultures were made every 3–4 months.

Morphological characters of the yeasts were studied on SDA, Sabouraud's dextrose broth—SDB (Conant *et al.*, 1954), Shear's cornmeal agar—CMA (Rawlins, 1933), carrot plugs—CP (Conant *et al.*, 1954) and potato extract water—PEW (Ainsworth, 1952). All cultures were incubated at 25–27 ° C. except PEW cultures which were incubated at 37° C. Fresh mounts made in lactophenol cotton blue were utilized for microscopic examinations.

For the study of sugar fermentations, cultures maintained on SDA were sub-cultured in 1% Difco peptone solution and incubated for 24 hours at 25–27° C. To 100 ml. of 1% peptone solution in distilled water 0·5 g. of NaCl was added, pH was adjusted to 7·6 and then 1 ml. of Andrade's indicator (16 ml. N. NaOH and 100 ml. of

0·5% aq. acid fuchsin) was added. In order to make 2% sugar solution, 0·3 g. of a sugar was added to 15 ml. of the above solution. Aliquots of approximately 4 ml. of different sugar solutions were inoculated with yeast cultures, grown in Difco peptone solution, and incubated at 25–27° C. for 7 days. Acid and gas production was recorded at the end of this period.

The *in vitro* effect of the antibiotic Nystatin (produced from *Streptomyces noursei* and manufactured by Sarabhai Chemicals under the Squibb trade mark "Mycostatin") was studied by the agar cup plate method. 48 hours old culture of yeast in SDB at 25–27° C. was adjusted to 60% light transmission. 2 ml. of this culture was added to 20 ml. SDA and plated. Four cups were then fixed in each plate and 0·2 ml. of freshly prepared Nystatin was added to each cup. Three concentrations 5, 50 & 500 units, of Nystatin were used. 4 cups per concentration, and the experiment was repeated twice. The inhibition zones were measured after 48 hours incubation.

Results and Discussion

Morphological and physiological characters of the yeasts (Y_1, Y_2, Y_3, Y_4) and their comparative *in vitro* sensitivity to Nystatin are presented in Tables I and II. A strain of *C. albicans*, obtained from the School of Tropical Medicine, Calcutta, has been included in these studies for the purpose of comparison. It will be seen from the tables that the yeasts studied fall into 3 groups. Y_2 and Y_3 show close resemblance to *C. albicans*, while Y_1 seems to be different in respect of mycelial character and maltose fermentation. All the 3 yeasts belong to the same sub-family Candidoideæ. The production of asci and ascospores, presence of round budding cells and the absence of mycelium in cultures on PEW, place the yeast Y_4 in the tribe Saccharomyceteæ of the subfamily Saccharomycoideæ (Skinner, Emmons and Tsuchiya, 1947).

Pathogenicity tests on mice were studied by the technique of Mankowski and Littleton (1954). Yeast Y_1, Y_2, Y_3 and *C. albicans* could be isolated in culture from the kidneys of the infected animals. Y_3 was able to cause the death of one out of the five mice inoculated with it. No death was caused by the sporogenous and non-mycelial yeast Y_4 and it could not be isolated from the kidneys. Sporogenous and non-mycelial yeasts have also been reported by others to be non-pathogenic (Ainsworth, 1952).

In vitro, all the yeasts including *C. albicans* were sensitive to Nystatin (Table II). At 5% level of significance (statistically) yeast Y_1 was less sensitive and Yeast Y_4 was more sensitive to Nystatin as compared with *C. albicans*. There was no difference in sensitivity of yeasts Y_2, Y_3 and *C. albicans*. The four yeasts fall into three groups according to their sensitivity to Nystatin also as was found to be the case on morphological and physiological grounds. Protective action of Nystatin against *C. albicans* and *Histoplasma capsulatum in vitro* and *in vivo* has been shown by Hazen *et al.* (1953) and Drouhet *et al.* (1956).

TABLE I

Showing the morphological and physiological characters of the yeasts Y_1, Y_2, Y_3, Y_4 and Candida albicans

Media	Macroscopic and Microscopic Examinations	Isolated yeasts and *C. albicans*				*Candida albicans*
		Y_1	Y_2	Y_3	Y_4	
SDA— 3 days old plate cultures	Macroscopic (surface colonies)	Creamy, 2–4 mm. diam.	Creamy, 1–2 mm. diam.	Same as Y_2	Dull white 1 mm. diam.	Same as Y_2
	Microscopic (submerged colonies)					
	Pseudomycelium	+	−	−	−	−
	True mycelium	−	+(little)	+	−	+
	Arthrospore	−	−	−	−	−
	Blastospore	+	+	+	+	+
	Macroscopic	No surface pellicle submerged turbid growth		Same as Y_1	Same as Y_1	Same as Y_1	Same as Y_1
SDB— 2 days old tube cultures	Microscopic						
	Pseudomycelium	+		−	−	−	−
	True mycelium	−		+	+	−	+
	Arthrospore	−		−	−	−	−
	Blastospore	+		+	+	+	+
CMA— 7 days old cultures	Microscopic Chlamydospore	+		+	+	+	+
PEW— 1 day old tube cultures	Microscopic						
	Pseudomycelium	+		−	−	−	−
	True mycelium	−		+	+	−	+
CP— 7 days old plug cultures	Microscopic Asci and ascospore	−		−	−	+	−
Monosaccharide	Glucose	*7·0	‡5·0 G	4·0 G	3·5 G	5·0 G	3·5 G
	Galactose	6·5	5·5	5·5	6·0	6·5	6·0
	Maltose	7·0	7·0	3·5 G	4·0 G	7·0	3·5 G
Disaccharide	Sucrose	7·5	6·5	6·5	6·5	7·5	6·0
	Lactose	7·0	7·0	7·0	7·0	7·0	7·0
Trisaccharide	Raffinose	7·5	7·5	7·5	7·5	7·5	7·5

* = pH of the control (uninoculated);
‡ = pH of the inoculated tubes;
G = Gas production.

TABLE II

Showing the in vitro *sensitivity of yeasts* Y_1, Y_2, Y_3, Y_4 *and* Candida albicans *to Nystatin*

Yeasts	No. of inhibition zones measured	Mean diameters of inhibition zones in mm. with 5, 50 and 500 units of Nystatin/cup.		
		5	50	500
Y_1 ..	8	10·0	15·1	19·3
Y_2 ..	8	10·0	16·1	21·9
Y_3 ..	8	10·1	15·5	22·0
Y_4 ..	8	12·1	19·1	22·8
C. albicans ..	8	10·9	16·3	21·9

SUMMARY

Four yeasts (Y_1, Y_2, Y_3 and Y_4) isolated from the fæces of a healthy man have been shown to fall in three groups on the basis of their morphological and physiological characters and also their sensitivity to Nystatin. Yeasts Y_2 and Y_3 have been found to be similar to *Candida albicans* while Y_1 and Y_4 were different from it and also from each other. Pathogenicity tests in mice have revealed that yeasts Y_1, Y_2, Y_3 and *C. albicans* are able to accumulate in the kidneys from where they could be reisolated. The sporogenous and non-mycelial yeast Y_4 was found to be non-pathogenic.

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CULTURE STUDIES IN THE GENUS *RICCIA* (MICH.) L.

III. Sporeling Germination in *R. trichocarpa* Howe—A Reinvestigation.*

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(Received for publication on December 7, 1957)

Introduction

R. trichocarpa, a very common North American ciliate species of *Riccia*, was instituted and described by Howe (1898) and some excellent illustrations and the range of distribution in America have been subsequently given by Schuster (1953). Till very recently this species was known only from America but it has now also been gathered from tropical Africa by Jones (1957). This recent discovery is rather significant as it throws open a great possibility of its being recorded, at a future date, from some more tropical countries including India.

R. trichocarpa has been worked out with respect to some of its morphological details as well as the stages in the sporeling germination by Campbell (1918). According to him (Campbell, 1918) the spores of this species "remain dormant during the dry summer months" and when "sown in autumn they germinate within a few days". Further, *the germ tube emerges through the tri-radiate mark* and the formation of the first rhizoid is rather delayed "until a number of divisions have been formed in the young thallus" and when formed "the first rhizoid arises at the base of the germ tube" being usually "separated by a septum from the germ tube". Subsequent study of the sporeling germination in several other species of *Riccia*, as shown below, has brought to light different details in developmental pattern of the sporelings.

From his excellent morphological investigations, including a study of the sporeling germination in *R. frostii* Aust. (*R. sanguinea* Kash.) Pandé, (1924) *for the first time* pointed out that a *distinct germ pore is formed opposite the tri-radiate mark*, on the outer face of the spore, and the germ tube emerges through this pore; *the tri-radiate mark being obviously not concerned in this process*. This view subsequently has received wide support from the works of Duthie & Garside (1936, 1939), Srinivasan (1940), Abeywickrama (1945) and Udar (1957 *a*, 1957 *b*). Also the study on sporeling germination in *R. billardieri* (Udar, 1957 *a*), *R. crystallina* (Udar, 1957 *b*) as well as *R. cruciata*, *R. discolor*, *R. gangetica* and *R. melanospora* (Udar, unpublished data)

* Contribution from the Department of Botany, Lucknow University, India, New Series, No. 33.

has revealed that *in culture the spores do not require a rest period for germination* and the first rhizoid *normally develops rather early* and *is a continuation of the germ tube being not separated from it by a septum.*

It is thus evident that the observations of Campbell (1918) on the sporeling development in *R. trichocarpa* radically differ from those subsequently obtained by the detailed study of some other species of *Riccia* (Pandé, 1924; Udar, 1957 *a*, 1957 *b*). It, therefore, appeared extremely surprising that one species should differ so fundamentally. In view of this anomaly Dr. S. K. Pandé, suggested to the author to study sporeling patterns in several species of *Riccia* growing in the country along with that in *R. trichocarpa* to be able to arrive at some definite conclusions regarding this aspect. A reinvestigation of the sporeling germination in *R. trichocarpa* has proved to be extremely interesting and the observations worth recording.

Material and Methods

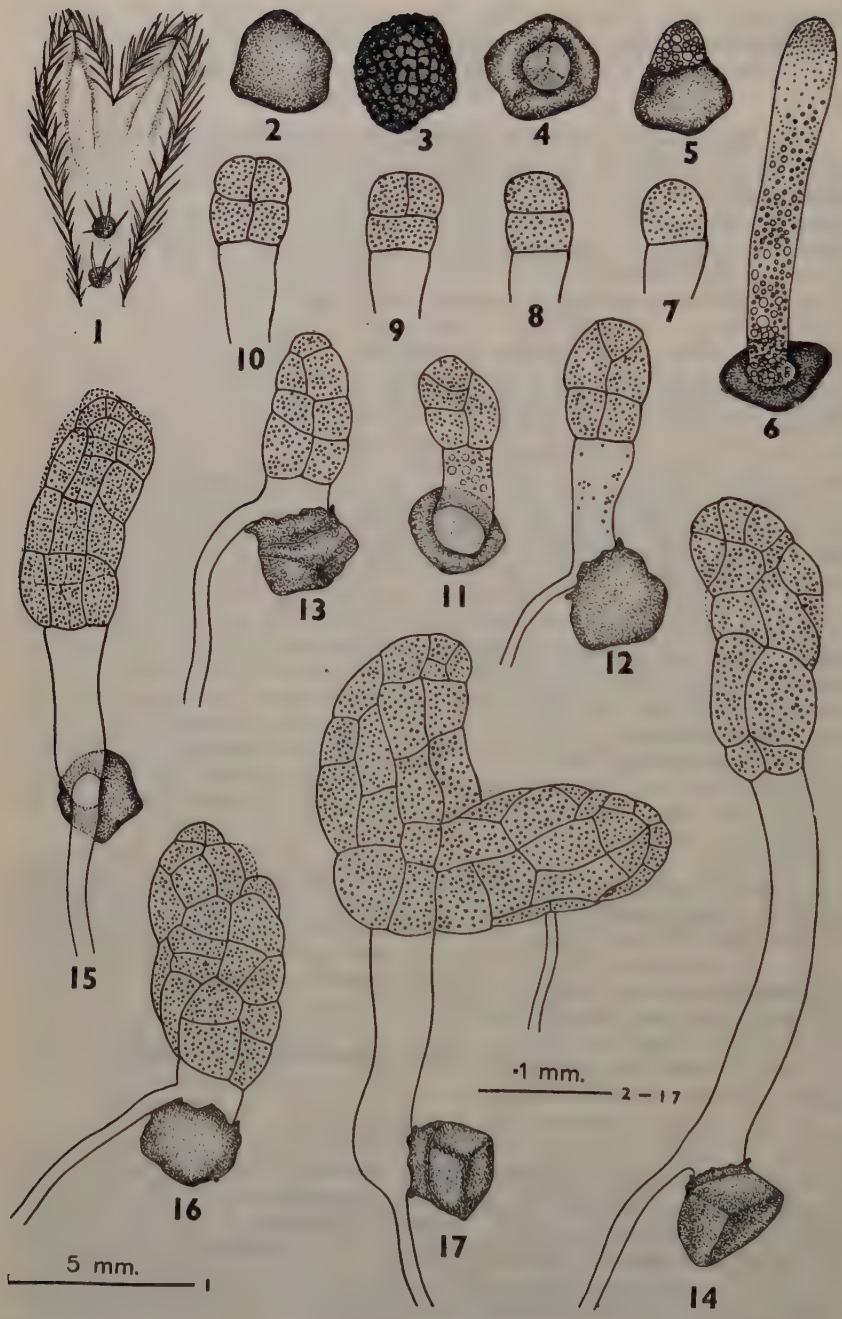
Through the courtesy of Dr. E. W. Jones beautiful specimens of *R. trichocarpa*, growing in tropical Africa, were obtained which on soaking in water regained the freshness of the living plants. The specimens were collected on July 24, 1955, from Jinja, Uganda, growing on very thin earth over ironstone in cart track on gently sloping plateau above Lake Victoria (E. W. Jones, No. 529). The plants are copiously fertile, bearing numerous capsules with mature spores. This species is characterized by the presence of numerous long hair-like cilia on the thallus which are invariably also present on the tissue covering the sporophytes dorsally (Fig. 1). The spores are perfectly dark and opaque at maturity, 90–120 μ in the maximum diameter, tetrahedral, reticulate with 9–12 reticulations across the outer face with angles of reticulations irregularly warty and thickened becoming papillose in profile (Figs. 2, 3).

Intact mature sporophytes were carefully isolated from the thalli and repeatedly washed with sterile water. The spores were cultured in sterilized covered Pyrex glass Petri dishes containing (*a*) sterile tap water, (*b*) sterilized full strength Knop's solution and (*c*) sterilized half strength Knop's solution. The usual constituents were used for preparing the Knop's solution.

In all the three cases the spores germinated but the growth was more vigorous in (*b*) and (*c*).

Observations

From the specimens utilized for the culture it is difficult to say whether a rest period is necessary for germination in *R. trichocarpa.* This aspect certainly needs a further investigation from a culture of the spores of freshly gathered plants. It is, however, clear that the spores have remained viable during the two years and a quarter they had been in storage and those collected on July 24, 1955 and cultured on November 3, 1957 germinated in about 7 days and showed several



FIGS. 1–17

FIGS. 1–17. Fig. 1. Thallus, dorsal. Note the large hair-like cilia. Fig. 2. A mature spore (perfectly dark and opaque). Fig. 3. Spore, outer face. Fig. 4. Spore showing a prominent germ pore opposite the tri-radiate mark. Fig. 5. Emergence of the germ papilla. Figs. 6–13. Early stages of the sporelings. Figs. 14–16. Advanced stages of sporelings. Fig. 17. A branched young gametophyte.

stages in another 3–4 days. The viability was in the neighbourhood of 50%. Nevertheless, a large number of sporelings were available for study.

The first evident indication of germination is the swelling of the spore (by water absorption) and its consequent transparency. The spores being very dark, the transparency is at best only comparative and never conspicuous in early stages. In about 5–6 days after culture a distinct pore (Fig. 4) is formed opposite the tri-radiate mark, on the outer face of the spore, through which a blunt papilla (germ tube) emerges (Fig. 5). This observation is in contrast to the emergence of the germ papilla through the tri-radiate mark as stated by Campbell (1918) for this species. The germ tube elongates (Fig. 6) and there is an aggregation of a large number of chloroplasts at the tip which conspicuously bulges out. A constant feature is also the presence of an equal number of germlings showing prominent suppression of the germ tube which remains extremely small. A transverse septum below the bulge cuts off the first cell of the germ plate (Fig. 7). Subsequently a two-celled germ plate is organized (Fig. 8). The upper of these two cells divides vertically (Fig. 9) and a similar division in the lower cell results in the formation of a 4-celled germ plate (Fig. 10). Occasionally the divisions are somewhat irregular and an apical cell is established rather early (Figs. 11, 12). Further growth of the germ plate is certainly due to this primary apical cell but this is subsequently replaced by the usual group of initial cells observed in the mature thallus.

The first rhizoid (Figs. 12–17) is formed as a direct continuation of the germ tube and is not separated from the germ tube by a septum as has been stated by Campbell (1918). This rhizoid appears rather early (Fig. 12) in contrast to its appearance at a relatively later stage observed by Campbell (1918, Fig. 9).

It would thus appear that the developmental patterns of the sporelings in *R. trichocarpa* do not exhibit those differences ascribed to it by Campbell (1918).

SUMMARY

1. The results obtained from a critical reinvestigation of the sporeling development in *R. trichocarpa* Howe have been described and the observations of Campbell (1918) have been discussed.

2. Mature spores from the plants of this species growing in tropical Africa and obtained through the courtesy of Dr. E. W. Jones were cultured for this investigation.

3. The spores have remained viable for about two years and a quarter that they had been in storage. The spores from the specimens

collected on July 24, 1955 germinated when cultured on November 3, 1957.

4. The germ tube emerges through a distinct pore formed on the outer surface of the spore and not through the tri-radiate mark as has been stated by Campbell (1918).

5. The first rhizoid arises rather early in development and is a direct continuation of the germ tube being not separated from it by a septum. According to Campbell (1918) the first rhizoid appears relatively late and gets separated by a septum from the germ tube.

6. *R. trichocarpa* conforms to the usual sporeling patterns known so far for other species worked out in detail (Pandé, 1924; Udar, 1957 *a*, 1957 *b*).

Acknowledgements

Grateful thanks are due to Dr. S. K. Pandé, D.Sc., for his keen interest and guidance in the preparation of this paper and to Dr. E. W. Jones, Imperial Institute of Forestry, U.K., for the excellent specimens of *R. trichocarpa* Howe utilized for the present investigation.

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STUDIES IN INDIAN ANTHOCEROTACEAE

II. The Morphology of *Anthoceros* cf. *gemmulosus* (Hattori) Pandé.[1]

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(Received for publication on November 16, 1957)

Introduction

In an earlier paper (Bhardwaj, 1950) the author communicated the results of his study of *Anthoceros crispulus* (Mont.) Douin.[3] The present article deals with the morphology of another species, *A.* cf. *gemmulosus* (Hattori) Pandé.

Since the publication of the results (Bhardwaj, 1950) on *A. crispulus* where an up-to-date historical review of important contributions to the morphology of *Anthoceros* and the allied genera had been incorporated, Proskauer (1951) from an examination of a few more species of *Anthoceros* L., has substantiated his earlier observations (1948, 1948 *a*) and has finally discussed the nature of various characteristics used in the classification of *Anthocerotales*. In the end, on the basis of his conception of the morphology of these plants he has defined the genera *Anthoceros* (Mich.) L. emend. Prosk., and *Phæoceros* Prosk. Recently Mehra and Handoo (1953) have published on the morphology of *A. erectus* Kash.

A. cf. *gemmulosus* has long, septate pseudoelaters and, according to Stephani's concept of the genera of the Anthocerotales, is referable to *Aspiromitus* (*Elateres longi, septati*). However, in view of Proskauer's (1948, 1951) latest findings it is referred here as a member of *Anthoceros* (Mich.) Prosk., as has been done by Schiffner and Pandé (Mss.).

Material and Method

A. cf. *gemmulosus* was collected by Pandé and Misra from the side of a hill stream near Munsyari (6,200′), mile 79, on Almora-Milam Road,

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[1] Part of the Ph.D. thesis approved by Lucknow University in 1952. Contributions from the Botany Department, Lucknow University, N.S. No. 34.

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[3] The identification of the Indian specimens as *A. crispulus* is based on a comparison with the description and material of *A. crispulus* (Schiffner, 1937, p. 24; *Exsiccati* sp. Nos. 1091, 1092, 1093). According to Proskauer (1948) the British material of this species is merely a form of *A. punctatus* L. In the Indian specimen, however, the antheridial body ranges from 78 μ to 105 μ the average size being 92 μ. This size is bigger than *A. punctatus* but smaller than *A. husnoti*. The size of the 4-celled pseudoelater (130–200 μ) is also midway between *A. punctatus* and *A. husnoti*.

in the Western Himalayas, in September 1936. Killing and fixing was done *in situ* in formacetic alcohol and chromoacetic combinations and the material was preserved in a mixture of equal parts of 70% alcohol and pure glycerine. When required for study, it was thoroughly washed in 70% alcohol and carefully dehydrated, cleared and embedded in the usual way. Sections were cut 2-4-6-10 microns thick and stained in safranin gentian-violet, safranin light-green and iron-alum hæmatoxylin. In the last case a saturated solution of picric acid was used for differentiation (Maheshwari, 1933).

A. cf. *gemmulosus*

Taxonomic Description

Dicœcious, terrestrial, light green, spongy, growing in dense cushions of overlapping longish fronds arranged in rosettes. Fronds bear spherical, cavernous subsessile vegetative bodies on the margin. These bodies contain copious mucilage and appear to serve for vegetative propagation. Female plants repeatedly branched, branches usually 10–15 mm long and 4–5 mm broad. Male plants thinner, smaller, once or twice forked, main branches up to 10 mm long and 2–3 mm broad, becoming slightly broader and lobed near the posterior end. *Involucre* solitary, 6–8 mm (*A. gemmulosus* 7–9 mm) long, cavernous. *Capsule* 20–50 mm long and 0·4 mm thick (*A. gemmulosus* 30–90 mm long and 0·7 mm thick), deshiscing by two valves, wall stomatiferous, stoma 65 $\mu \times 30\,\mu$. *Spore* reticulate—spinulate distally and spinulate, with a prominent triradiate mark proximally, 34 μ in diameter, spines single or bifurcate and blunt, but prominent. *Pseudoelaters* brown, 300 μ (*A. gemmulosus* 365 μ) long, frequently branched, fragile, walls strong but collapsible on drying, lumen wide, smooth and light coloured. *Andrœcia* in a median row on the main thallus as well as on the lobes, prominent, giving the thallus a blistered appearance, 0·4–0·6 mm in diameter, subspherical or oval, opening by a well-defined central, elliptical aperture, the latter measuring 60 $\mu \times 80\,\mu$. *Antheridia* numerous, usually up to 30 in a chamber, cylindrical and long-stalked; the body of the antheridium 180 μ long (*A. gemmulosus* 184 μ) stalk 180 μ long and four cells thick. The antheridial wall consists of four, well-defined tiers of regularly arranged cells, the cells of the apical tier are triangular.

A. gemmulosus has been established by Pandé (Schiffner and Pandé Mss.) after a study of the type material (Hattori, 1947), and a specimen collected by Decoly and Schaul from the neighbourhood of Darjeeling in the Sikkim-Himalayas. I had an opportunity to examine the type as well as the Indian material, together with the manuscript and drawings of this species, through the kindness of Dr. Pandé.

A comparison of the West-Himalayan plant with *A. gemmulosus* shows that the former is merely a diminutive form of the latter. It has smaller thallus and spongy bodies, shorter involucre as well as sporophyte, and smaller pseudoelaters as compared to *A. gemmulosus*. On the other hand the size of the antheridial body is nearly equal in both.

The surface cells in the Munsyari specimens possess two chloroplasts whereas in the case of *A. gemmulosus* there is a single chloroplast. In view of these differences the Munsyari specimen is not referred as *A. gemmulosus* but as *A.* cf. *gemmulosus*. An opinion on the final taxonomic status of *A.* cf. *gemmulosus* is deferred till the conclusions of my investigations on the morphology of some other Indian species of *Anthoceros* (Mich.) Prosk., have been published. In the present state of our knowledge it is difficult to decide whether *A.* cf. *gemmulosus* should be treated as a variety or a sub-species of *A. gemmulosus*.

Morphological Description

Gametophyte.—The species is dimorphous and as a rule, the female plants normally form rosettes, but due to overcrowding, perfect rosettes are often not developed. The female and male thalli usually grow intermingled. The female frond (Text-Fig. 1) is longish and repeatedly lobed. The margin of the lobes is crisped and deeply dissected into lobules. The male fronds (Text-Fig. 2, Pl. II, Fig. 1) are deeply forked, lobes being linear and further 2–3 lobed at the posterior end. Many of the lobules bear spongy bodies which usually arise as minute, triangular outgrowths with their tips later swelling up (Text-Figs. 3–6). A mature spongy body is sub-spherical in outline with a notch which indicates the location of the growing point. Each spongy body contains mucilage cavities and *Nostoc* colonies, and is capable of germination to develop into a new plant (Text-Fig. 7).

The thallus has a number of growing points, each with an apical cell of the type found in other species of *Anthoceros*. The apical cell divides regularly (Text-Fig. 23) as described by Campbell (1918, p. 125). Externally it is protected by a thick, mucilaginous sheath.

The thallus is thick and spongy as in other species of the genus and has large cavities filled with mucilage. In a vertical section (Text-Fig. 8) the interior of the thallus is mostly occupied by cavities, separated from each other by one cell thick partitions. In the median part of the thallus, the cavities may be seen in 2–3 series, recalling the condition seen in certain Marchantiaceæ (Sethi, 1931). In a superficial view of the thallus, observed under the low power of a microscope, the cavities can be seen running obliquely backward from the margin towards the median part (Text-Fig. 1).

The first evidence of the formation of the mucilage chambers is seen a few cells behind the apical cell (Text-Fig. 8). These appear in the form of small intercellular spaces filled with deeply stained mucilage. Nearer the growing point of the thallus the cavities are always in one row, but with the growth of the thallus these gradually increase in size and extend obliquely towards the dorsal surface resulting into superimposition of the cavities in the median part of the thallus. In older parts of the thallus the cavities are usually devoid of mucilage.

The tissue of the gametophyte, around the foot of the sporophyte, is compact and the cells are smaller. The epidermal cells usually contain

two chloroplasts (Text-Fig. 9; Pl. II, Fig. 2). The chloroplast is discoid with a thicker middle region and appears to be spongy in the material preserved in fluid. The centre is occupied by a group of minute pyrenoid bodies (Pl. II, Fig. 3).

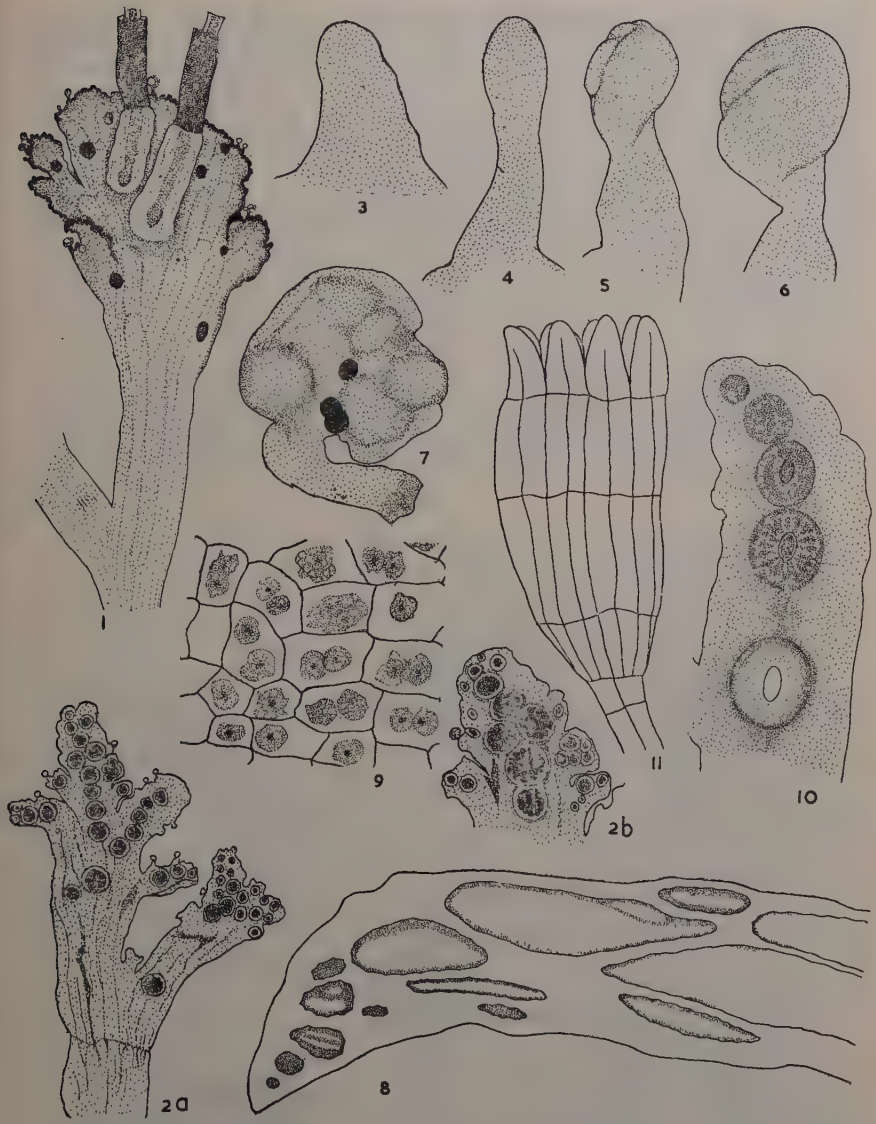
Nostoc colonies lie deeply embedded in the thallus and are irregularly distributed.

Sex Organs

Andrœcium.—The andrœcia are developed in acropetal succession, more or less in a median row, on the dorsal surface of the thallus (Text-Figs. 2 *a*, *b*). The mature andrœcial chambers are very prominent and appear as hemispherical on the surface (Pl. II, Fig. 1). Dehisced andrœcia assume conical shape, opening out by a central, elliptical aperture (Text-Fig. 10). The dehiscence is apparently effected by the disintegration of the central portion of the chamber roof (Text-Fig. 10, Pl. II, Fig. 4). In the chamber, the antheridia arise from the centre of the floor and are borne in one (rarely two) bunch. Each bunch carries antheridia in various stages of development. The number of antheridia in a chamber is large, and up to 30 could easily be counted.

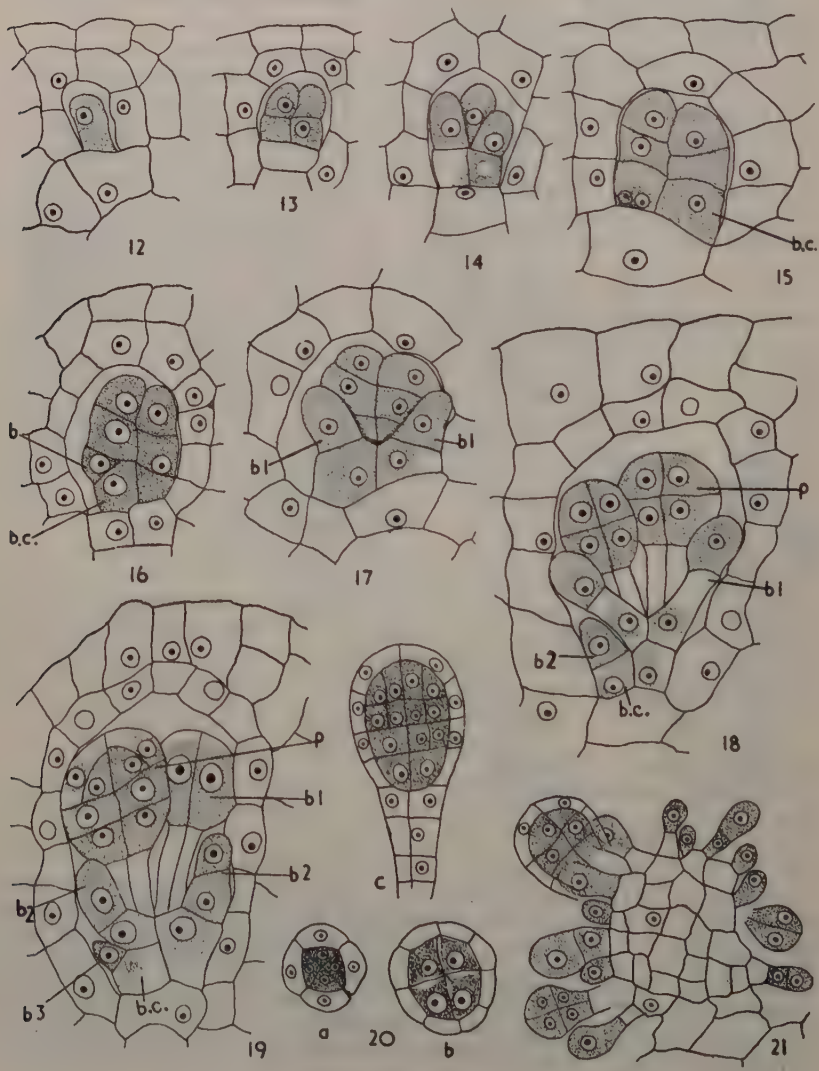
The primary initial, producing the andrœcium, was not seen. Presumably it lies a few cells behind the apical cell. The earliest stage observed by the author (Text-Fig. 12) shows a small chamber with one-celled primary antheridial initial. At this stage the roof of the chamber is already two cells high. In the primary antheridial initial, as Text-Figs. 13 and 14 would suggest, two intersecting vertical walls are laid down, forming four antheridial-mother-cells (in Text-Fig. 13 only two of these are seen), each one of which is subsequently divided into two cells by a transverse wall resulting into a lower cell and an upper cell (Pl. II, Fig. 4). The latter presumably divides again transversely as suggested by the three-celled filamentous body (Text-Fig. 15) of each antheridial-mother-cell observed. Out of these three cells, as the subsequent stages reveal, the top cell forms the body, the middle one produces the stalk of the primary antheridium while the bottom cell or '*basal-cell*' forms the primordium for an active *meristematic cushion* producing successive crops of secondary antheridia.

Secondary antheridia.—The secondary antheridia arise from the four, primary basal-cells lying below the stalks of the primary antheridia (Text-Figs. 16–18). In this process the basal-cell, on its free lateral side, cuts off a triangular cell by means of an oblique wall (Text-Fig. 16; Pl. II, Fig. 6) which extends from about the middle of its upper wall to the outer lateral wall a little above the middle. The triangular cell, thus produced, is the bud initial (Text-Fig. 16 *b*), which subsequently divides into two by a transverse wall. The lower one of these produces the stalk while upper one produces the body of the secondary antheridium precisely in the same way as in the case of the primary antheridium. Likewise each of the four-basal-cells (*b.c.*) produce secondary antheridia (Text-Fig. 17 shows two such bud initials). As the development proceeds the bud initial (Text-Fig. 18 b_1) comes to lie on the dorsal



TEXT-FIGS. 1–11. Fig. 1. A lobe of female thallus showing two sporophytes (basal portion only). Note the crisped margin of the thallus bearing the spongy bodies, ×4. Fig. 2 *a*. Part of a lobe of male plant showing distribution of androecia, ×4. Fig. 2 *b*. A part of the same enlarged, × 32. Figs. 3–6. Spongy bodies in various stages of development, × 42. Fig. 7. Germinating spongy body, ×31. Fig. 8. V.s. of thallus through growing point, × 41. Fig. 9. Surface cells showing double chloroplasts, × 190. Fig. 10. Part of a lobe of the plant enlarged to show androecial opening, ×16. Fig. 11. Dehisced antheridium, ×190.

surface of the parent basal-cell due to the lateral growth of the latter. The laterally extended part of the basal-cell subsequently cuts off another bud initial (Text-Figs. 18 b_2 and 19 b_2, Pl. II, Fig. 7) in the same way as the primary basal-cell does. It seems that as the primary basal-cells extend laterally, vertical walls are developed in them separating the extended parts as secondary basal-cells which continue the budding activity further. Such a process is, presumably, repeated a number of times and secondary antheridia continue to be successively budded off from the primary and the secondary basal-cells successively, ulti-



TEXT-FIGS. 12–21

TEXT-FIGS. 12–21. Fig. 12. Young androecial chamber with primary antheridial initial, ×550. Fig. 13. Androecial chamber with two-celled antheridia (only two out of four are seen in the Fig.), ×550. Fig. 14. Androecial chamber showing three young antheridia; somewhat older than those seen in Fig. 13, × 550. Fig. 15. Androecium showing the two young 3-celled antheridia; the lowest cell is the basal-cell, the middle one is the stalk-cell and the top one the body-cell of the antheridium, ×550. Fig. 16. Young antheridia. Note the lateral bud (*b*) from the upper part of one of the basal-cells, ×550. Fig. 17. Similar as Fig. 16. The lateral budding is from both the basal-cells, ×550. Fig. 18. A young chamber showing two of the primary antheridia (*p*), two lateral buds of first order (*b*1) and one young lateral bud of 2nd order (*b*2), ×550. Fig. 19. Another chamber showing likewise as in Fig. 17. ×550. Fig. 20. Young antheridia—(*a*) *t.s.* of the body with four central spermatogenous cells and four peripheral wall cells. (*b*) older stage. (*c*) A young antheridium, ×370. Fig. 21. Transverse section through a basal cushion showing antheridia of different ages. Note also the young secondary buds at the periphery, ×325.

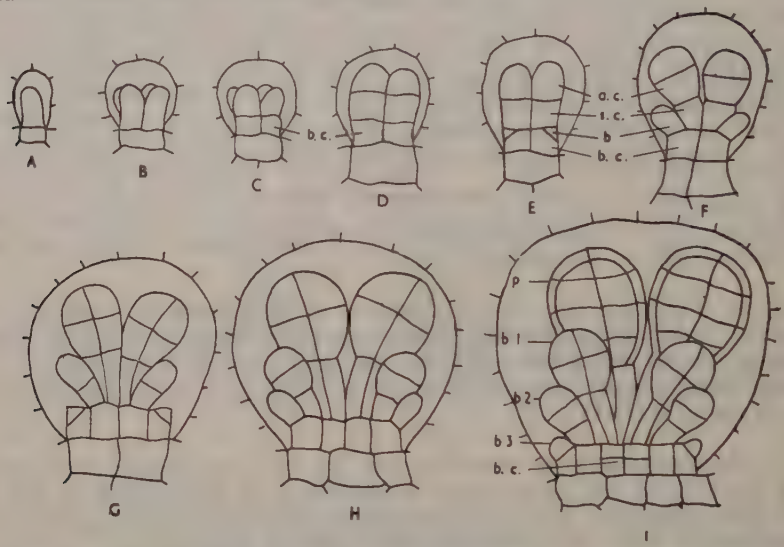
mately forming a layer of basal-cells or a 'basal cushion' (Text-Fig. 21) which carries antheridia of different ages on its dorsal surface, the oldest being nearest the centre and the youngest towards the periphery. A semi-diagrammatic representation of the sequence in antheridial budding is given in Text-Fig. 22.

Antheridium.—The development of the antheridum (Text-Figs. 18–21) follows the same course as described by Rink (1935, p. 95) for *A. sampalocensis*. In *A.* cf. *gemmulosus* the four tiers of cells in the antheridial wall are differentiated early in development, just as in *A. sampalocensis* (Rink, 1935) and *A. husnoti* (Proskauer, 1951, p. 335).

The mature antheridium is club-shaped consisting of an obovate or cylindrical body, borne on a long, four cells thick, multi-tiered stalk. The wall of the antheridium is one cell thick and consists of large cells arranged in four vertical tiers. The arrangement of these can be best studied in a dehisced antheridium (Text-Fig. 11). The lower three tiers consist of vertically elongated rectangular cells, while the uppermost tier consists of eight triangular cells, with their apices towards the top. The outer wall in each of these triangular cells is partially divided by a median longitudinal thickening extending from the base to a little below the apex (Text-Fig. 10). In dehisced antheridia, mounted in water, the triangular cells get swollen and turgid with their apices curved outwards. Towards the base, the cells of the lowest tier of the wall are very much narrower. The cells of the middle tiers occasionally develop secondary partitions.

Archegonium.—The origin and development of the archegonium as far as studied (Text-Figs. 23–26), is of the usual type. The number of neck-canal-cells, in a mature archegonium, is five (Text-Fig. 26) or six. The cover cells are only four in number. The ventral-canal-cell lies just above the egg and is smaller than the egg. Both the egg and the ventral-canal-cell possess highly granular cytoplasm, a nucleus and a chloroplast (Text-Fig. 28). In a young archegonium the egg-nucleus, except for the nucleolus, is achromatic. It usually shows a few chromatin granules. However, just before the egg is ready for fertilization, its nucleus shows great avidity for stains (Text-Figs. 29, 30). In the

egg cytoplasm at this stage, usually a small, spherical, highly chromatic body (Text-Figs. 29, 30, *sph*) is also present. The exact nature of this inclusion could not be determined.



TEXT-FIG. 22. Semi-diagrammatic representation of the sequence in antheridial budding—*a.c.*, Antheridial cell; *b.c.*, Basal-cell; *s.c.*, Stalk-cell; *b*1, *b*2, *b*3, Bud initials; *p*. Primary antheridium.

FERTILIZATION

In a number of archegonia, some stages of fertilization were observed (Text-Figs. 31–33). Text-Figure 31 shows that before the fusion of the male and female nuclei the egg-cell may usually enlarge and occupy the entire cavity of the venter. At this stage, within the egg-cell, one (possibly two, Text-Fig. 31) nucleus may be seen lying a short distance away from or in contact with the egg nucleus. The egg nucleus is achromatic at this stage showing a lightly stained nucleolus and a few chromatin threads, but the other nuclei, presumably ♂ nuclei, are highly chromatic. In Text-Figs. 32 and 33, the chromatic male nucleus is seen in contact with the egg nucleus. In Text-Fig. 32, a portion of the male nucleus is overlapping a part of the female nucleus. Sharp (1934, p. 233) who observed syngamy in *Anthoceros*, has also figured the male and female nuclei lying only in close contact. Similar stages have been observed in *Riccia* (Black, 1913), in *Ricciocarpus* (Garber, 1904), in *Reboulia* (Dupler, 1922), and in *Preissia* (Haupt, 1926).

Actual fusion of the male and female nuclei in *A.* cf. *gemmulosus* has not been seen. It is, however, difficult to say anything regarding the final stage in the process. It may be that the actual fusion is delayed as observed by Haupt (1926, p. 45) in *Preissia*. It is also possible that the actual fusion of the male and female nuclei never takes place and

the two develop their chromosomes separately which then take their places in a common mitotic spindle as reported in *Sphærocarpus* (Rickett, 1923).

In *Preissia*, Graham (1918) and Haupt (1926) described as well as figured centrosomes with astral rays at either poles of the egg nucleus during syngamy. Such structures have not been observed in *A.* cf. *gemmulosus*.

Embryo

The first division in the oospore as well as the subsequent stages in early embryogeny were not seen. The youngest embryo observed (Text-Fig. 34) shows a three-tiered, twelve-celled, pear-shaped embryo. A three-tiered embryo slightly more mature than the one in Text-Fig. 34, is seen in Text-Fig. 35 (Pl. II, Fig. 8) where diagonal or oblique septation has already proceeded in the cells of the basal tier. It seems that in this species four-tiered stage of the embryo as reported in *A. crispulus* (Bhardwaj, *loc. cit.*) is not attained.

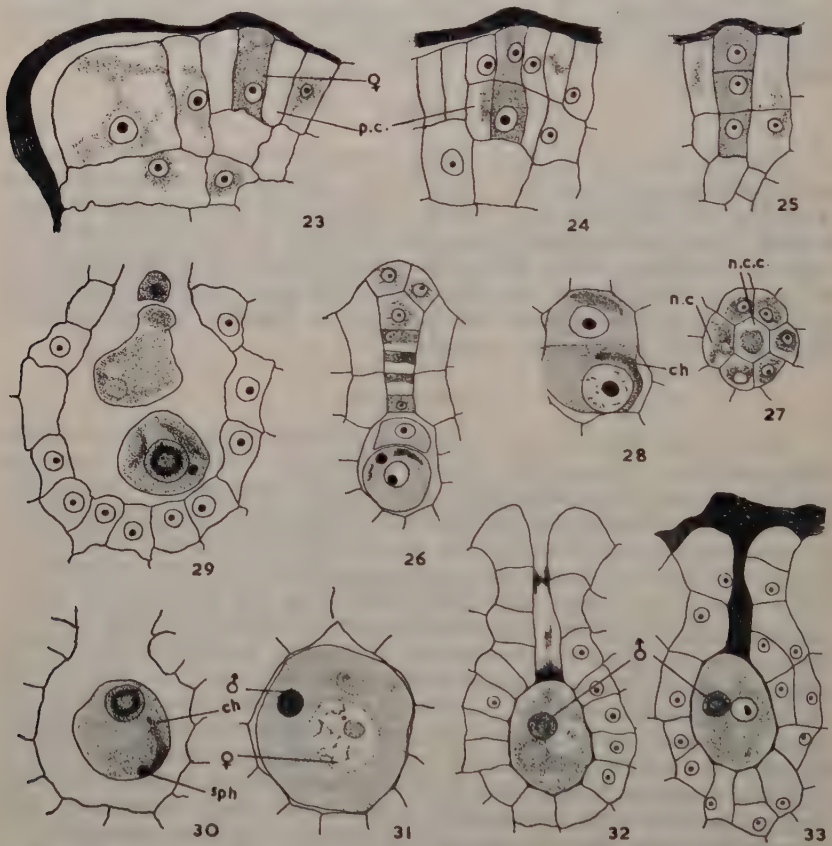
Sporophyte

Foot.—The foot of the young sporophyte consists of an easily distinguishable, outwardly curved horizontal layer of vertically elongated cells (Text-Fig. 36). This layer, presumably, arises by repeated oblique septation of the cells in the basal tier of the embryo the commencement of which has already been noted in Text-Fig. 35. Below this layer of somewhat elongated cells of the foot a number of other, vacuolated, large cells occur (Text-Fig. 36) followed by small, roundish cells which are separated from the former by a thin layer of mucilage. The large vacuolated cells appear to have been parts of the elongated foot-cells and the small rounded cells are the cells of the thallus. In mature sporophytes the foot is very large and bulbous having a superficial lining layer of prismatic palisade-like cells with denser and granular contents (Pl. II, Fig. 9). This lining layer of the foot is separated from the thallus only by a layer of mucilage without the intervening layer of large, vacuolated cells of the young condition. The inner cells of the foot are vacuolated and not regularly arranged.

Archesporium.—The archesporium originates from the inner layer of the amphithecium (Text-Fig. 36) and extends to the base of the columella and is usually one cell thick in its basal region.

Columella.—In young sporophytes the endothecium is normally 16 cells thick and develops into the columella. In mature capsules, the columella is a long, massive body and has smooth surface. In the region of the seta the columella is 16 cells thick of which only 4-cell-rows are seen in l.s. (Pl. III, Fig. 10) but in mature parts of the capsule it usually becomes very massive and may consist of 36–49 rows of cells (6–7 cell-rows seen in l.s., Pl. III, Fig. 11). The increase in the thickness of the columella is presumably due to secondary divisions in the cells of the endothecium.

Sporogenous tissue.—In the young sporophyte, the archesporium is only one cell thick throughout, but it increases in thickness as the capsule grows older, the first indication of this being noticed in the amphithecial cells above and around the apex of the columella (Text-



FIGS. 23–33. Fig. 23. Apical cell and a young archegonial initial (♀) with peripheral cells (*p.c.*), ×415. Fig. 24. Older archegonium. The axial cell and peripheral cells have divided by a transverse wall, ×415. Fig. 25. Older archegonium than the one shown in the previous figure. The axial cells have further divided into the venter cell (bottom), primary neck-canal-cell (centre) and the cover initial (top), ×415. Fig. 26. A mature archegonium with cover cells, 5 neck-canal cells, a ventral-canal-cell and an egg-cell, ×415. Fig. 27. Transverse section of an archegonium in the region of the neck showing six neck-cells (*n.c.*) and a neck-canal-cell (*n.c.c.*), ×415. Fig. 28. Vertical section of the mature archegonium in the region of the venter showing the ventral-canal-cell and egg-cell, each of which has a nucleus and a chloroplast, ×680. Fig. 29. Venter of a mature archegonium. The canal cells are disorganising, ×680. Fig. 30. Mature egg-cell with deeply stained nucleus, elongated chloroplast (*ch*) and a chromatic spherical body (*sph*), ×680. Fig. 31. An oospore with a large egg-nucleus (♀) and a male (♂) nucleus, ×680. Fig. 32. Oospore showing male nucleus (♂) partly covering the egg-nucleus, ×415. Fig. 33. Another oospore showing the egg-nucleus and male nucleus (♂) lying in contact, ×270.

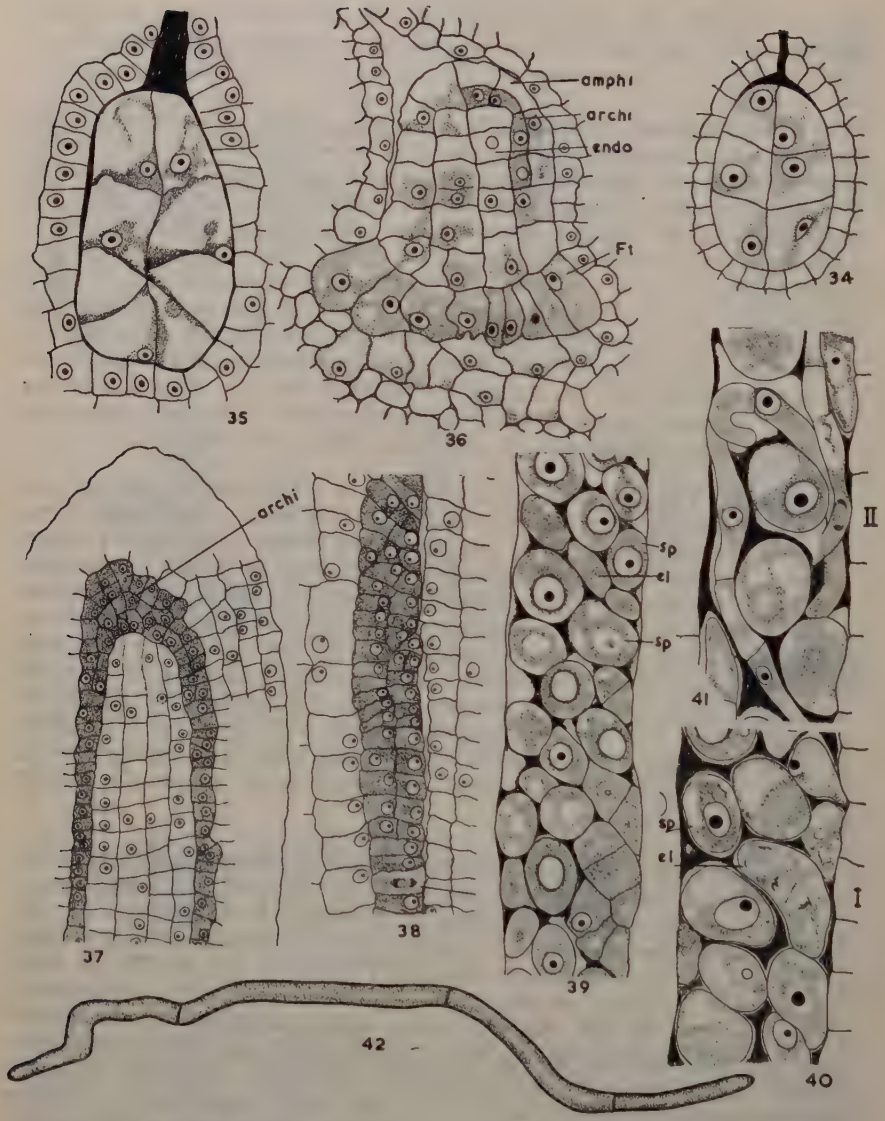
Fig. 37, Pl. III, Fig. 12). Subsequently this multiplication of the sporogenous tissue extends up to the region of the seta (Text-Fig. 38, Pl. III, Fig. 10).

The young archesporial cells are small, cubical or rectangular and have granular contents. The distinction between the cells that would later produce the spore-mother-cells and the pseudoelater-mother-cells is noticeable even in young condition (Text-Fig. 38). Higher up, in the older parts of the capsule, spore-mother-cells become spherical or oval and are comparatively much larger (Text-Fig. 39), while the pseudoelator-mother-cells are smaller, more or less rectangular and laterally elongated. It is also evident from Text-Fig. 39 that by the time this stage is reached the young spore-mother-cells (*sp*) and the pseudoelater-mother-cells (*el*) get arranged obliquely along the axis in the spore-sac, in alternate rows, and are roughly in the ratio of 1 : 1. This alternation of rows of spore- and pseudoelater-mother-cells is however soon lost as they increase in size and displace each other (Text-Fig. 40).

Spore.—The spore-mother-cells have a large central nucleus and a mass of granular cytoplasm with one or two small chloroplasts (Text-Fig. 41) and ultimately, after two successive divisions, produce a spore-tetrad. Mature spores are dark brown or black in colour, tetrahedral in shape, *i.e.*, having a hemispherical distal face and a low, pyramidal proximal face with the three pyramic planes converging to meet along a triradiate ridge whose arms extend from the proximal pole to a little behind the equator of the spore. The pyramic areas are ornamented with small spines which are sparser towards the centre. The distal face is ornamented with low ridges (*muri*) peaked with simple or bifid spines at close intervals. These *muri* are sometimes irregularly interconnected forming an imperfect reticulum enclosing large or small meshes (Pl. III, Figs. 15–17).

Pseudoelater.—The pseudoelater-mother-cells and the spore-mother-cells are sister cells as they are derived from the undifferentiated sporogenous tissue by the same number of cell divisions (Text-Figs. 38, 39). Similar to the development of a spore-tetrad, each pseudoelater-mother-cell undergoes two successive divisions (Text-Figs. 40, 41; Pl. III, Figs. 13, 14) and produces an elongated filamentous four-celled pseudoelater (Text-Fig. 42; Pl. III, Fig. 18). *Thus each pseudoelater is a compound structure and homologous to a spore-tetrad*, developing into a long, four-celled, vermiform structure with strong but thin walls and rounded, tapering ends (Text-Fig. 43; Pl. III, Figs. 18–20) which usually lie free from one another in the spore-sac. Due to want of space the pseudoelators become closely packed and haphazardly arranged (Pl. III, Fig. 11) but they are never secondarily fused, end to end, with each other (Pl. III, Fig. 18). Occasionally a component cell in a pseudoelater may be branched (Pl. III, Fig. 11).

There is no evidence of any elaborate thickening or induration on the inside of the wall and the lumen is wide (Pl. III, Fig. 20). In each cell, the nucleus is usually seen till the pseudoelaters are almost mature.



FIGS. 34–42. Fig. 34. Twelve-celled, 3-tiered embryo, ×415. Fig. 35. A slightly older, 3-tiered embryo with oblique septa in the basal tier, ×415. Fig. 36. Young capsule showing single cell layered foot (*Ft*), endothecium (*endo*), amphithecium (*amphi*), and delimitation of the archesporium (*archi*), ×270. Fig. 37. Archesporium in young capsule. Note the increase in the archesporium at the apex of the columella, ×190. Fig. 38. Archesporium showing multiple-layered archesporium and the alternation of spore- and pseudoelater-mother-cells especially in the lower parts, ×280. Fig. 39. Young spore (*sp*) and pseudoelater-mother-cells (*el*) obliquely arranged in alternating rows, ×340. Fig. 40. Sporogenous tissue. Note one of the pseudoelater-mother-cells undergoing first nuclear division (I). ×340. Fig. 41. Same as above showing 2nd nuclear division (II) in one of the cells of a two-celled pseudoelater, ×340. Fig. 42. A mature pseudoelater ×280.

The walls of the pseudoelater-cells collapse on drying so that the latter assume flat and twisted appearance.

Capsule wall.—The wall of the capsule is 5–6 cells thick and, as compared to the fertile tissue, it occupies the bulk of the thickness of the capsule. Its outermost layer forms the epidermis with normal stomata distributed evenly all over the surface. The stomatal aperture is linear and is bounded by two large uni-nucleate guard cells. The epidermal cells are considerably longer than broad and their radial and outer walls are highly thickened. No abnormal or degenerate stomata were ever seen. The internal cells of the capsule wall usually contain two chloroplasts.

In young capsules the calyptra is often carried at the tip of the capsule but usually it is shed before the capsule is ready for dehiscence. The capsule dehisces by two valves which show marked twisting.

Discussion

The present study has contributed mainly towards the elucidation of the mode of development of the secondary antheridia and the morphology of pseudoelater in a species of *Anthoceros* besides throwing light on other features whose importance we are unable to realise in the present state of our knowledge.

It has been shown that in *A.* cf. *gemmulosus* the secondary antheridia are produced by dorso-lateral budding from the basal-cells lying below the primary antheridia. These basal-cells are differentiated from the antheridial-mother-cells simultaneously as the primary antheridial cells. Each primary basal-cell is potentially meristematic and is capable of budding out secondary antheridia. It expands itself laterally, pushing secondary antheridia on to its dorsal surface, and producing a succession of secondary basal-cells which continue the budding activity further. Ultimately a whole bunch of antheridia is borne by a many-celled, basal cushion composed of primary and secondary basal-cells.

In *A. crispulus* (Bhardwaj, 1950, p. 151), where only a few secondary antheridia are produced, it was interpreted, in the two-celled stage of the antheridial-mother-cell (Bhardwaj, *loc. cit.*, Text-Fig. 3), that the lower cell forms the stalk and the upper cell the body of the antheridium. However, in the light of my findings for *A.* cf. *gemmulosus* and after a further examination of a number of preparations of *A. crispulus*, it can be stated that in the latter species as well, in the two-celled stage the lower cell is a basal-cell and the upper one is the antheridial cell giving rise to both the stalk as well as the body. The identity of basal-cells as well as the fact that in *A. crispulus* also the secondary antheridia arise from a small basal cushion consisting of only four primary basal-cells is apparent from a section figured earlier (Bhardwaj, 1950, Text-Fig. 6).

Regarding the mode of secondary antheridial budding in *A. fusiformis* Aust., Campbell (1918, p. 130), who studied the details of the process of antheridial development, states that the antheridial initial

divides by two intersecting vertical walls resulting in four antheridial-mother-cells each of which cuts off an upper, body-cell and a lower stalk-cell. He sums up the origin of the secondary antheridia by saying that these arise by budding from the bases of the older antheridia (*loc. cit.*, p. 130). Proskauer (1951, p. 337) has figured a somewhat similar condition for *A. husnoti* stating that in *Anthoceros* new antheridia are proliferated from the bases of older ones.

The statements of Campbell as well as Proskauer are not in agreement with my findings as the secondary antheridia are not budded from the base of older antheridia but from the cells lying below them. They also do not say anything regarding the details of budding and apparently they did not persue the study any further. On the other hand according to Rink (1935, p. 95), in *A. sampalocensis* the antheridial-mother-cell (= *antheridial initial*) divides by vertical walls at right angles to each other, into four, eight or even more cells, each of which later develops into an antheridium. He states to have counted 12 such young antheridia in a small cavity (Rink, *loc. cit.*, Text-Fig. 9 *b*). Thus according to him all these additional antheridia in *A. sampalocensis* are due to repeated segmentation of the antheridial-mother-cell and thus primary, which is fundamentally different from the condition observed in *A.* cf. *gemmulosus* and *A. crispulus*.

The first division of the oospore was not seen so that it is not known whether in *A.* cf. *gemmulosus* the first septum is transverse, similar to *A. crispulus* (Bhardwaj, *loc. cit.*) or vertical as in *A. fusiformis* (Campbell, *loc. cit.*).

In *A. crispulus* (Bhardwaj, 1950) a four-tiered embryo leading to the differentiation of foot, seta and capsule region is stated to reach, but in *A.* cf. *gemmulosus* such differentiation starts at the 3-tiered stage. The variation, apparently, ensues due to the diagonal division of the cells in the hypo-basal tier of the 12-celled embryo in *A.* cf. *gemmulosus* rather than transverse division as in the other two species.

All the species of *Anthoceros* investigated by Bartlett (1928) are characterised by a one-cell thick sporogenous tissue. So is also the case in *A. crispulus* studied by me. But in *A.* cf. *gemmulosus* the mature sporogenous tissue consists of 2–3 cell layers in thickness. Multiple-layered sporogenous tissue is not the usual characteristic of *Anthoceros* so that in this respect *A.* cf. *gemmulosus* presents a significant deviation from the normal condition associated with the genus.

The columella in *A.* cf. *gemmulosus* is more than 16-cells thick, similar to the condition in *A. fusiformis* (Campbell, 1924), whereas in *A. crispulus* the columella remains only 16 cells thick in mature capsules.

The morphology of pseudoelaters in Anthocerotales had lately become a debated problem. Goebel and Suessenguth (1927) who tried to study this aspect found that the sterile cells of the archesporium, in *A. punctatus* L., ultimately develop into a network of sterile cells in the meshes of which the spore-mother-cells lie and that this network during

dehiscence breaks up into pieces which are the pseudoelaters. Evidently they implied thereby that the pseudoelaters in *Anthoceros* and the allied genera are almost morphologically undefined. Similar, though slightly more explanatory, statement has been made by Proskauer (1951, p. 337) who states,

"They (**sterile cells*) form tiers alternating with tiers of spore-mother-cells in *Notothylas*; in the other genera they are interspersed with the fertile cells, grow between them, and may form a more or less complete girder system linked by secondary contacts, in the meshes of which the spore-mother-cells lie. In *Dendroceros*, *Megaceros*, and most species of *Anthoceros* and *Phæoceros* they separate in rows of more or less elongated cells, which may or may not show branching. In how far these structures are produced by division of individual sterile cells, and in how far by secondary adhesion between them is not clear."

My findings, as already given above, clearly show that a pseudoelater in *A.* cf. *gemmulosus* is a four-celled elongate structure with both of its ends smooth and tapering. A complete pseudoelater is developed after two successive divisions from a sterile pseudoelater-mother-cell which is homologous to a spore-mother-cell. These pseudoelaters remain free from each other throughout their development, and even after maturity there is no evidence of a network or of secondary linkage between them.

The tendency of the pseudoelaters to break up into one-, two- or three-celled pieces is a natural consequence of their compound origin. This tendency is parallel to the tendency of the spore-tetrads, with which complete pseudoelaters are homologous, to fall apart into individual spores on maturity.

As compared to *A. crispulus*, the pseudoelaters in *A.* cf. *gemmulosus* are longer and narrower.

Summary

1. *A.* cf. *gemmulosus* (Hattori) Pandé is diœcious and dimorphous (Text-Figs. 1, 2). The thallus has numerous, large mucilage chambers (Text-Fig. 8). Sessile or sub-sessile, spongy, vegetative bodies are (Text-Figs. 3–7) present along the margin. Epidermal cells often contain two chloroplasts (Text-Fig. 9). Each chloroplast has a group of pyrenoid bodies in the centre.

2. The androœcia are large and appear as prominent superficial pustules (Text-Fig. 2) on the dorsal surface. Each androœcium opens by a definite aperture (Text-Fig. 10). The details of the development of the androœcium and antheridium (Text-Figs. 12–22) have been followed. The androœcia are polyandrous and in a mature chamber usually up to 30 antheridia have been counted.

3. The secondary antheridia develop successively by budding from the basal-cells lying below the stalk and cut off very early from the

* Italics by the author.

antheridial-mother-cell (Text-Figs. 16, 19). The budding activity continues, almost idefinitely, producing numerous antheridia, borne on a cushion developed by the lateral multiplication of the basal-cells (Text-Fig. 22).

4. The antheridial wall consists of four tiers of regularly arranged elongated cells. The cells of the apical tier (Text-Fig. 11) are triangular and open out under moist condition apparently, by turgor, in a characteristic manner thus serving as an operculum.

5. The mature archegonium is of the usual type having 5–6 neck-canal-cells (Text-Fig. 26). During fertilization usually a male nucleus is seen lying near the egg-nucleus (Text-Figs. 32, 33) but the actual fusion of the two nuclei has not been seen.

6. The details of embryogeny conform to the usual anthocerotean type. The embryo becomes a three-tiered, 12-celled body before delimitation of the foot, seta and capsule instead of the four-tiered, 16-celled body.

7. The foot develops from the basal tier by oblique septation of its cells while the seta and capsule are produced from the middle and top tiers respectively (Text-Fig. 35) in the usual way. The foot in a young sporogonium consists of a regularly arranged lining layer of closely packed, longish cells (Text-Fig. 36) and stays as such in a mature foot clearly delimiting it from the gametophytic tissue.

8. The seta is 30–40 cells high and meristematic. The columella arises from the endothecium (Text-Fig. 37) and is 16-cells thick in the meristematic region (Pl. III, Fig. 10), but 36–49 cells thick in the older parts (Pl. III, Fig. 11). It thins out towards the apex. The cells of the columella are smooth.

9. The archesporium develops from the inner amphithecium. In mature capsules the sporogenous tissue above the meristematic region and in the apical region becomes two- or three-layered. The spore and pseudoelater forming cells regularly alternate with each other in the spore-sac (Text-Fig. 39).

10. The spores are 36 μ in diameter, spinulate on the proximal face and reticulate-spinulate on the distal face. The spines are sparser and smaller on the proximal face. The distal reticulum is irregular and its spines are bifid or single and blunt.

11. Each pseudoelater develops from its mother-cell by two consecutive nuclear divisions (Text-Figs. 41, 42), into a four-celled, long, structure and has free, tapering ends (Text-Fig. 43). It is homologous with the spore-tetrad. The pseudoelaters are brown in colour and functional but easily break up into smaller pieces.

12. The wall of the sporophyte is 6–7-cell layered and the epidermis is stomatiferous. The wall cells normally contain two chloroplasts.

Acknowledgements

I am thankful to Dr. S. K. Pandé for the material, guidance and critical suggestions throughout the progress of this work. I am obliged to Prof. S. N. Das Gupta, Head of the Botany Department, Lucknow University, for research facilities and encouragement.

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Explanation of Plates

Plate II

Fig. 1. Male fronds bearing androecia which bulge out prominently, ×5·2.

Fig. 2. Surface cells of the thallus showing chloroplasts, ×450.

Fig. 3. V.s. of chloroplasts showing pyrenoid bodies, ×1,500.

Fig. 4. Part of the thallus showing two mound-like androecia. Note the frilled opening in one, ×42·5.

Fig. 5. Young androecial chamber showing two-celled primary antheridial initials, ×680.

Fig. 6. Young androecial chamber showing young, 3-celled primary antheridia the lowest cell being the basal-cell, the middle being the stalk-cell and the upper the body-cell. In one of the antheridia the basal-cell has already cut off a triangular cell which is the bud initia (secondary antheridium), ×680.

Fig. 7. Young androecial chamber in v.s. showing 2 primary antheridia, 2 secondary bud initials of 1st generation (b_1) and one bud initial of the 2nd generation (b_2) and the basal cells (*b.c.*), ×680.

Fig. 8. A 3-tiered embryo with the cells of the basal tier showing oblique septation, ×680.

Fig. 9. Foot of mature sporophyte with the external lining layer, ×100.

Plate III

Fig. 10. L.s. of young capsule showing multiple-layered archesporium in the meristematic region. ×265.

Fig. 11. L.s. of mature capsule showing columella and the disposition of spore-tetrads and pesudoelaters. × 265.

Fig. 12. L.s. of apical portion of a young capsule showing multiple-layered archesporium. ×265.

Fig. 13. A part of sporogenous tissue in l.s. showing first nuclear division (*x*) in a pseudoelater-mother-cell, ×500.

Fig. 14. A mature part of the sporogenous tissue in the same l.s. as Fig. 13 showing second nuclear division (*x*) in one of the cells of a two-celled pseudoelater, ×500.

Fig. 15. Spore in proximal view showing the triradiate ridge and spines in the pryamic areas, ×500.

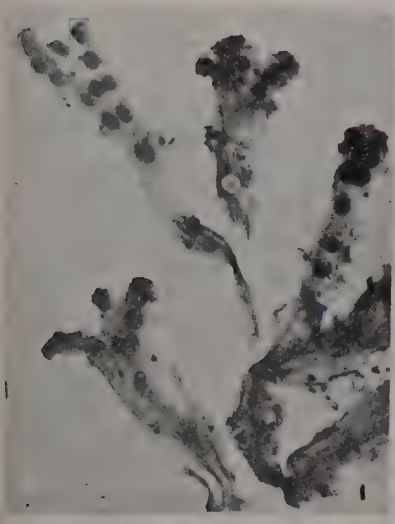
Fig. 16. Spore in equatorial view showing reticulation and spines, ×500.

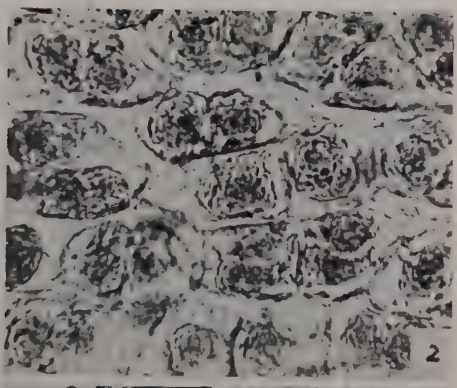
Fig. 17. Spore in distal view showing the reticulation and spines borne on the *muri*, ×500.

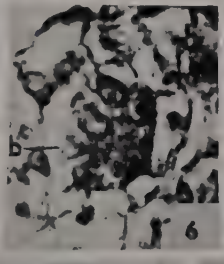
Fig. 18. Tapering, rounded, free ends of two pseudoelaters in the spore-sac, ×450.

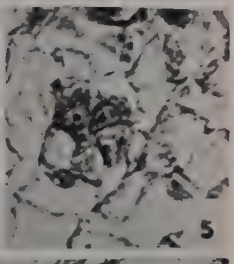
Fig. 19. A complete pseudoelater and a spore, ×187.

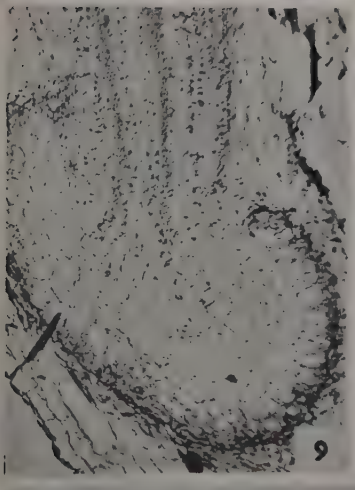
Fig. 20. A part of pseudœlater showing wide, smooth lumen and its contents, ×680.

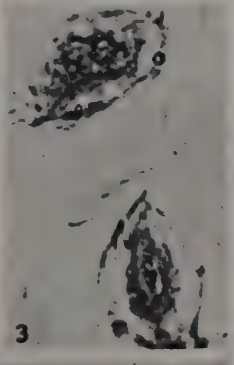


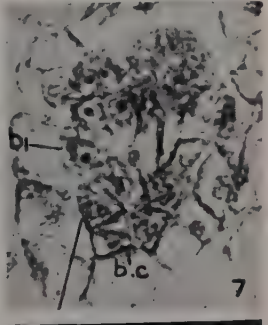


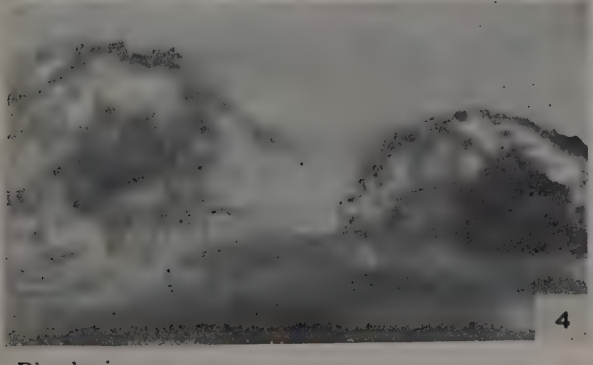












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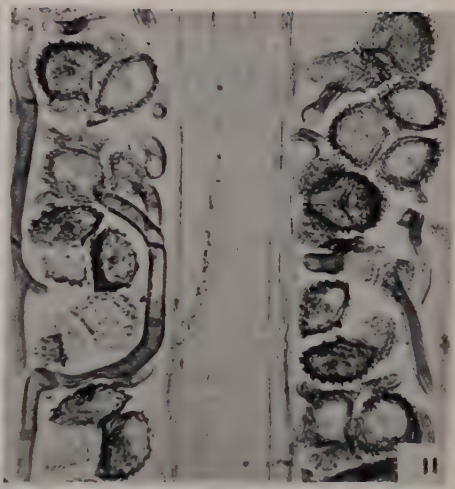

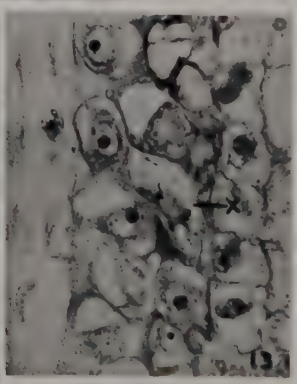

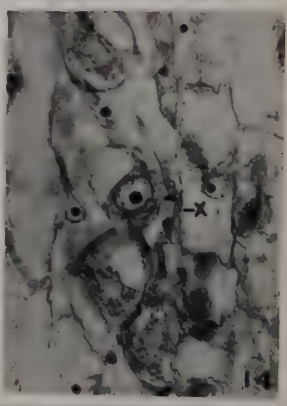

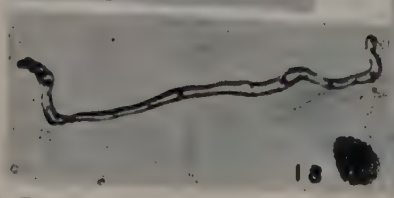

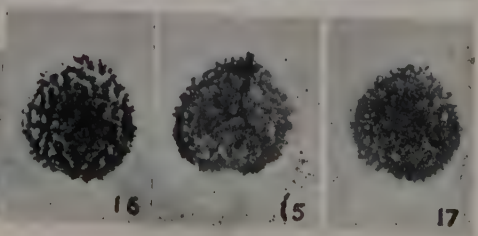

D. C. Bhardwaj

STUDIES ON THE CYTOLOGY AND PHYLOGENY OF THE PTERIDOPHYTES

V. Observations on the Isœtaceæ

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Received for publication on December 26, 1957

Introduction

The family Isœtaceæ contains but one genus *Isætes*, most of the species of which occur in the cooler temperate latitudes. A few species are also distributed in the tropics. In South India this family is represented by three species, namely, *I. coromandelina* L. (McCann, 1934; Bharadwaja, 1935), *I. sahyadri* (Mahabale, 1938) and *I. sampathkumarani* (Rao, 1944). The present paper deals with the cytology of *I. sampathkumarani* and *I. coromandelina* from South India.

Materials for investigation were collected from different places in South India and grown in the Botanical Garden of the Kerala University. Root tip studies were made mostly from plants grown in the garden while meiosis was studied from sporangia fixed in the field. The cytological and photographic techniques followed were similar to those described earlier (Ninan, 1955, 1956 *b*).

Cytological Observations

I. sampathkumarani Rao.—This species was collected from Bangalore and Waltair. Cytological examination of root tips alone was possible due to the failure of onset of meiosis in the few plants grown in the garden. Preparations of somatic mitosis of the Bangalore material showed the presence of 66 chromosomes in root tip cells (Pl. IV, Fig. 4). The same number of chromosomes has also been observed in the Waltair material. The somatic chromosomes of this species have median or submedian constrictions and vary from 2–4 μ in length.

I. coromandelina L.—This species is widely distributed in South India and was collected from Kovalam, Chakkai (in Trivandrum City), Veli, Quilon and Crangannore in Kerala and from Waltair in Andhra Pradesh. Almost all the plants collected from the various localities were seen to be megasporangiate. Microsporangiate plants were obtained only from Chakkai. Out of several hundreds of plants examined in the field, only three were found to be microsporangiate while a single plant was bisporangiate. The microsporangiate plants showed only 2–4 sporangia per plant, most of the leaves being sterile. Microsporangia can easily be distinguished by their almost cordate shape

and smaller size compared with megasporangia. But in external appearance there is no difference between microsporangiate and megasporangiate plants.

All the microsporangiate and megasporangiate plants collected from the above localities were found to be diploids with 22 chromosomes and a fragment (B-chromosome?) in root tip cells (Pl. IV, Figs. 1 and 2). Most of the chromosomes have median or submedian constrictions. Two chromosomes were seen to be satellited in some materials, while others showed only a single satellite chromosome. The size of the chromosome varies from 2–5·3 μ. The B-chromosome is very small and is less than 1 μ in size. In the anaphase of somatic mitosis the split halves of the B-chromosomes are seen separating to opposite poles showing that it has a kinetochore.

A single plant from the Kovalam collections, which survived in the garden for a few years, showed luxuriant vegetative growth and was larger in size than the diploid plants. Cytological examination showed this to be a triploid with 33 chromosomes and a fragment in root tip cells (Pl. IV, Fig. 3). The fragment in the triploid is seen to be appreciably smaller than that in the diploid. The somatic chromosomes of the triploid also show median or submedian constrictions. They are found to vary from 3·3–6 μ in length. This is the only triploid plant obtained for study and was found to be megasporangiate.

Meiosis in both micro- and megasporangia of the diploid, and megasporangia of the triploid, was studied.

Meiosis in megaspore mother cells of the diploid.—Though the megasporangia of *Isætes* are larger than those of any other Pteridophyte, the number of megaspore mother cells per sporangium is very limited and in smear preparations of whole sporangia only a few spore mother cells could be obtained on a slide. The early prophase chromosomes appear as long drawnout threads intertwined at certain points. The cell illustrated in Pl. IV, Fig. 5 would easily be mistaken for a "pachytene" of normal meiosis. But as later stages show this is only thickened single chromosome threads and not paired strands. At a later stage (Pl. V, Fig. 6) corresponding to early diplotene of normal meiosis the duality is also clearly seen in some chromosomes. Occasionally, associations of chromosomes have been observed at this stage in some cells (Pl. V, Fig. 7), while in others almost all the chromosomes remain as univalents without any sort of associations (Pl. V, Fig. 8). In most cells, end to end associations of a few chromosomes near the nucleolus have been observed at diplotene (Pl. V, Fig. 9) and diakinesis (Pl. VI, Fig. 10). At metaphase, chromosome associations in the forms of chains, rings, cross-shapes, etc., have been observed in many cells (Pl. VI, Figs. 12, 14, 15). The cell illustrated in Pl. VI, Fig. 13 shows lateral associations of chromosomes. The number of chromosomes involved in these associations as well as the number of such groups in a cell varies from cell to cell. The data provided below show the type of associations in a few cells.

TABLE I

No. of cells	"Groups of 4"	"Groups of 3"	"Groups of 2"	Univalents	2*n* Number
1	3	..	2	7	22+1
2	2	2	2	5	22+1
3	4	..	..	7	22+1
4	1	..	1	17	22+1
5	1	1	3	10	22+1
6	1	..	..	19	22+1
7	2	1	4	4	22+1

In cases where rings, or chains of four, or cross-shapes of four chromosomes are seen at metaphase, they resemble closely the behaviour noted in translocation heterozygotes. The end to end associations of chromosomes observed in a large majority of cells may be due to the fact that the earlier associations at pachytene are only shown at metaphase by the associations of the ends of chromosomes; perhaps the result of complete terminalisation, which is reported to be the usual feature in all structural hybrids (Darlington, 1937). The associations of three chromosomes at a point seen in certain cells represent triple chiasmata (Pl. VI, Fig. 11). Lateral associations of chromosomes seen at metaphase in some cells may be the restult of lateral chiasmata. The formation of triple and lateral chiasmata also points to the fact that we are dealing in this case with what is presumably a translocation heterozygote.

Anaphase separation is very regular in cells with complete asynapsis and 22 chromosomes are seen moving to opposite poles indicating that there is an equational division of the chromosomes (Pl. VII, Fig. 16). In other cases anaphase separation is not strictly regular and there are differences of one or two chromosomes at the opposite poles. In some cells associations of anaphase chromosomes have also been observed (Pl. VII, Fig. 17); and it is pertinent to note in this connection that in such cells the early meiotic chromosomes mostly show no associations. The two groups of anaphase chromosomes later reorganise to form two interkinetic nuclei. Though tetrad nuclei have been observed, second division stages were not seen in any of the preparations examined. The formation of tetrad nuclei further shows that there is a second division in most of the spore mother cells. The spores resulting from regular anaphase separation contain the normal diploid chromosome

complement. In cells with irregular anaphase separation the resulting spores contain abnormal complements.

Meiosis in microsporangia of the diploid.—It is easy to follow the different stages of division in the microsporangium due to the availability of a large number of spore mother cells in a single sporangium. Early stages of meiosis show that, as in some megaspore mother cells, there is no pairing. At diplotene and diakinesis 22 separate univalent chromosomes and a fragment can be observed in most cells (Pl. VII, Fig. 18). Unlike their counterparts on the female side the univalent nature of the chromosomes could be easily made out at all stages of division. At metaphase they appear very much like well-condensed somatic chromosomes. After metaphase I, quite different sequences of events are observed in different cells. In some, there is no division of chromosomes at metaphase; the whole group of chromosomes forms a nucleus which represents the nucleus of the single spore formed from it. In others there is regular anaphase separation leading to the formation of two telophase nuclei both of which may form dyads, or as in certain cases, one of them may divide a second time forming triads or both may divide and form regular tetrads. In a large majority of cases, however, anaphase separation is irregular and lagging chromosomes at various stages of movement from the equator to the poles could be observed. These laggards, which fail to reach the poles, form varying numbers of micronuclei. As many as 16 micronuclei have been observed in certain cells. After anaphase I, there is regular wall formation and the two daughter cells formed develop into dyads which may be one of the following types:—

(1) with a single large nucleus and no micronuclei,

(2) with a single large nucleus and one or more micronuclei,

(3) with varying numbers of micronuclei.

In certain cells however, there is a second wall formation at right angles to the first in one or both the daughter cells leading to the formation of triads or tetrads, each containing varying numbers of nuclei of different sizes (Pl. VII, Fig. 19). Again, after the micronuclei are organised, in some cells there are periclinal divisions forming varying numbers of spores (polyspores) of different shapes and nuclear contents. Linear tetrads with one or more micronuclei in some cells (in addition to the single large nucleus in each cell) have also been encountered. Most of the spores are dyads and are rounded in outline. Occasionally joint dyads are also formed as a result of improper cytokinesis.

Meiosis in megaspore mother cells of the triploid.—A detailed study of the various stages of meiosis in the megasporangia was not possible due to the inadequacy of sporangial material. As already stated, only a single triploid plant was available for study and a single sporangium only showed the critical stages of division. Early stages of meiosis in megaspore mother cells resemble those of the diploid. Certain spore mother cells, however, show signs of degeneration. The pachytene

chromosomes are visibly double and reveal clearly the relational coilign of chromonemata (Pl. VIII, Fig. 20). Diplotene and diakinesis were not obtained and whether there is chiasma formation or not, is not known. At metaphase however, the chomosomes are seen to be associated in groups of three or more (Pl. VIII, Fig. 21). This is followed by an interkinesis in which two or three nuclei of different sizes are formed (Pl. VIII, Figs. 22, 23). Soon after this, the chromosomes appear to divide mitotically. There is almost regular anaphase separation in some cells while it is quite irregular in others (Pl. VIII, Fig. 24). Some of the anaphase chromosomes are associated in chains of three or two while the others remain single (Pl. VIII, Fig. 25). Whether there is a second division in cells with normal anaphase separation is not known; however, the production of dyads would suggest that in some of the spore mother cells the second division is suppressed.

Discussion

Asynapsis and apogamy in I. coromandelina.—All plants of *Isœtes coromandelina* L. examined in this study show complete or partial failure of chromosome pairing at meiosis. In spore mother cells showing partial synapsis, often a few bivalents, trivalents or multivalents are organised. In this respect, *I. coromandelina* resembles the apogamous diploid forms of *Pteris cretica* described by Manton (1950), in which also there is the formation of univalents, bivalents and multivalents. Manton (1950) regards this situation in the diploid *P. cretica* as the result of hybridization between two related species with much, though not complete, homology between the chromosomes of the two gametic sets. She, however, recognizes another probability that the irregular pairing resulting in the formation of univalents and multivalents in *P. cretica* may actually have arisen by an accumulation of internal chromosome changes (translocations and the like). Apogamy in *P. cretica* according to this interpretation, might have arisen not by hybridization (which she believes is the case in the ferns as a whole), but by internal chromosome changes. As far as the ferns are concerned, Manton's contention that hybridization may actually cause apogamy seems to be supported, since no case of obligate apogamy has been found occurring as a local variant within a pure species. In *I. coromandelina*, all the collections examined from South India were found to be apogamous (no sexual form of this has so far been reported). The author is inclined to cast doubt on the accuracy of the report of Ekambaram and Venkatanathan (1933) describing the formation of regular bivalents in this species (in which case the meiosis would be regular and reproduction normal). These authors have failed to note even the correct chromosome number of the species and their observations may not be relied on in this context. It might be said that the univalents in the megaspore mother cells observed in the present study may be mistaken for bivalents and the contraction of unpaired chromosomes with median or nearly median constrictions give bivalent-like appearances.

If sexual species of *I. coromandelina* do occur side by side with the apogamous forms, then it is easy to assume that apogamy might have

arisen in this species by the accumulation of chromosome mutations in an originally sexual species. The fact that no trace of a sexual form has been found in this species need not invalidate the assumption of such an origin of apogamy, since, it is probable that the apogamous forms might have replaced the sexual species (from which they might have supposedly originated), due to the selective advantage of their diploid gametophytes. Such a process working for a long period of time (as the history of this genus might lead us to expect) would result in the complete elimination of the sexual forms. Further, chromosome associations in the form of rings, chains or crosses observed in the diploids with partial synapsis, and the triple and lateral chiasmata in them are clearly suggestive of structural changes (translocations, etc.) in the chromosomes. The accumulation of such changes might also result in the establishment of high heterozygosity of chromosomes as to result in total asynapsis in certain cases. Once such heterozygosity of the chromosomes is established this combination of genes might be preserved as a result of equational chromosome division at "meiosis" following asynapsis. *I. coromandelina* is thus in all probability a structural hybrid. It does not seem possible in the light of these evidences to conceive that this is a species hybrid.

If there is regular formation of viable microspores, the diploid female gametophytes developed from unreduced megaspores would be fertilised and triploids or tetraploids would result. But, as a result of the very irregular meiosis in most of the microspore mother cells, almost all the microspores formed are nonviable. However, it is already seen that along with the nonviable combinations there would be some that are normal and these may fertilize the diploid gametophytes. The triploids might have been formed in this way. That unreduced eggs function only rarely in the production of polyploid offspring (Sharp, 1943) is also seen from the fact that no tetraploids have so far been encountered, and the triploids are extremely rare.

Normally in triploids in which asynapsis is not a factor, sterility is usually observed. But in asynaptic triploids the intervention of apogamy might preserve the triploids since there are chances that megaspores with the full chromosome complement of the triploid parent may be produced as a result of equational division in "meiosis". The incidence of apogamy in the diploids offsets the effects of nonviability of the microspores as far as reproduction is concerned. Apogamy is thus seen to be of primary importance in the reproduction of these forms. Levan (1940) has shown that among asynaptic forms of *Allium amplectens* apogamous seed formation preserves the triploids and that the triploids seem to be most common and as effective as the tetrapliods. In *I. coromandelina* also the triploid plant shows luxuriant vegetative growth and is more sturdy than the diploids.

Phylogenetic considerations of the Isætaceæ.—The various species of the genus *Isætes* so far studied show haploid chromosome numbers like $n = 10$, 11, 22, 33 and 54–56, as given in the table below:—

TABLE II

Chromosome numbers in Isœtes

Species	Chromosome Number		Author
	n	2*n*	
Present Study:			
I. coromandelina ..	22+1	22+1	Ninan
I. coromandelina ..	33+1	33+1	Ninan
I. sampathkumarani ..	..	66	Ninan
Previous Reports:			
I. hystrix	10	20	Manton, 1950
I. echinospora	11	..	Ekstrand, 1920
I. asiatica	..	22	Takamine, 1921
I. japonica	..	43–45	Takamine, 1921
I. japonica	33	..	Yuasa, 1935
I. muricata	..	24–26	Dunlop,1949
I. lacustris	54–56	c.100	Manton, 1950
I. echinospora	..	c.100	Manton, 1950

Haploid numbers like $n = 11$, 22, 33, c.55, etc., show that there is a polyploid series in this genus based on the number $n = 11$. Previous reports show intraspecific polyploidy in *I. japonica* and *I. echinospora*. The present study has shown that *I. coromandelina* also exhibits intraspecific polyploidy; both diploids and triploids are present within the same species. All plants of *I. coromandelina* examined in this study showed a small extra-chromosome in addition to the normal chromosome complement. The presence of a somatic chromosome number of $2n = 24$–26 in *I. muricata* and 43–45 in *I. japonica* (Table I) might also indicate the occurrence of extra-chromosomes assuming that the chromosome count is correct. *I. coromandelina*, *I. japonica* and *I. muricata* thus show a tendency for increase in chromosome numbers. *I. hystrix* with $n = 10$ (Manton, 1950) demonstrates the opposite tendency for decrease in chromosome number. In *Isœtes*, therefore, both polyploidy and aneuploidy are of importance in speciation.

Coming to certain phylogenetic aspects in the light of evidence of chromosome numbers in *Isœtes*, it may be observed that the basic haploid number 11, characteristic of this genus, is shared by other ancient genera of Pteridophytes also. The presence of $n = 22$ in *Osmunda*, *Todea* and *Leptopteris* (Manton, 1950, 1954; Manton and Sledge, 1954; Ninan, 1956 *d*), $n = 77$ in *Ceratopteris* (Ninan, 1956 *e*) and numbers in multiples of 11 in species of *Lycopodium* (Delay, 1953; Mehra and Verma, 1957) provides examples of this. The finding of a number as low as 11 in *Isœtes* gives additional direct evidence of the

existence of ancestral types of Pteridophytes with 11 as the basic chromosome number.

The two heterosporous genera *Isœtes* and *Selaginella* show fundamentally low chromosome numbers like $n = 9$ in *Selaginella* and $n = 10$ and 11 in *Isœtes*. This contrasts strangely with the situation in other ancient genera of Pteridophytes like *Psilotum*, *Tmesipteris*, *Lycopodium*, *Phylloglossum*, *Ophioglossum*, etc., which possess very high chromosome numbers like $n = 104$ in *Psilotum* (Ninan, 1956 *c*), $n = 204$–10 in *Tmesipteris* (Barber, 1954), $2n = 502$–10 in *Phylloglossum* (Blackwood, 1953), $n = 136$, 165–70 and $2n = $ c.405 in *Lycopodium* species (Mehra and Verma, 1957 ; Ninan, 1958 *b*) and $n = 120$, 240, 480, c.570 and c.630 in *Ophioglossum* (Abraham and Ninan, 1954; Ninan, 1956 *a*, 1958 *a*). Evidences discussed elsewhere (Ninan, 1956 *a*, *b*, *c*) show that these high chromosome numbers have probably evolved in the course of evolution from much simpler numbers like 13, 15, etc. These observations together with the presence of numbers like $n = 9$ in *Selaginella* and $n = 10$ and 11 in *Isœtes* indicate that in the distant past the cytological situation of the Pteridophytes might have been simple and the chromosome numbers fundamentally low, more or less similar to those found in a large majority of the present-day angiosperms.

Regarding the relationship between *Selaginella* and *Isœtes*, other evidences bearing on these two genera indicate that there is neither clear nor close relation between them (Eames, 1936). The multiciliate spermatozoid, the absence of a strobilus and supensor, the large leaves and epiphyllous sporangia in *Isœtes* are all in striking contrast to the situation in *Selaginella*. However, in the possession of heterospory, they are apparently related, though heterospory may have arisen independently in the two genera. Cytological evidence also shows that there is no clear relationship between these two genera. They are separated by unrelated base numbers like 9 and 11 and in the possession of such low numbers they are exceptional in the Pteridophytes.

Summary

1. The cytology of *Isœtes coromandelina* and *I. sampathkumarani* from South India is described. *I. coromandelina* shows intraspecific polyploidy with $2n = 22 + 1$ (diploid) and $2n = 33 + 1$ (triploid), while *I. sampathkumarani* is hexaploid with $2n = 66$.

2. In the megaspore mother cells of *I. coromandelina* there is no chromosome reduction during "meiosis" and consequently megaspores with the unreduced number of chromosomes are formed. The irregularities of division in the microspore mother cells of the diploid result in unequal chromosome distribution in the microspores, which are mostly nonviable.

3. Apogamy has been demonstrated in *I. coromandelina*. It is suggested that apogamy in this species is the result of accumulation of structural hybridity rather than the consequence of hybridization.

4. The results of this study taken together with previous reports of chromosome numbers in this genus show that there is a polyploid series in *Isætes* based on the haploid number $n = 11$; diploid, triploid, tetraploid, hexaploid and decaploid types occur in nature.

Acknowledgement

This investigation was carried out under the supervision of Prof. A. Abraham, Head of the Department of Botany, University College, Trivandrum. The author is greatly indebted to Prof. Abraham for valuable guidance and encouragement. His thanks are also due to the Ministry of Education, Government of India, for the award of a Senior Research Scholarship and to the National Institute of Sciences of India for a Research Fellowship.

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EXPLANATION OF PLATES

PLATE IV

FIG. 1. Mitosis in a root tip cell from a bisporangiate plant of *Isætes coromandelina* L. (diploid) showing 22 chromosomes and a fragment, ×900.

FIG. 2. Somatic mitosis in a megasporangiate plant of *I. coromandelina* L. $2n = 22 + 1$, ×900.

FIG. 3. Mitosis in the triploid *I. coromandelina* L. 33 chromosomes and a small fragment are present, ×900.

FIG. 4. Mitosis in a root tip cell of *I. sampathkumarani* Rao. $2n = 66$, ×900.

FIG. 5. Meiotic prophase in a megaspore mother cell of the diploid *I. coromandelina* L. The chromosome threads appear like those in a normal pachytene, but are unpaired strands, ×900.

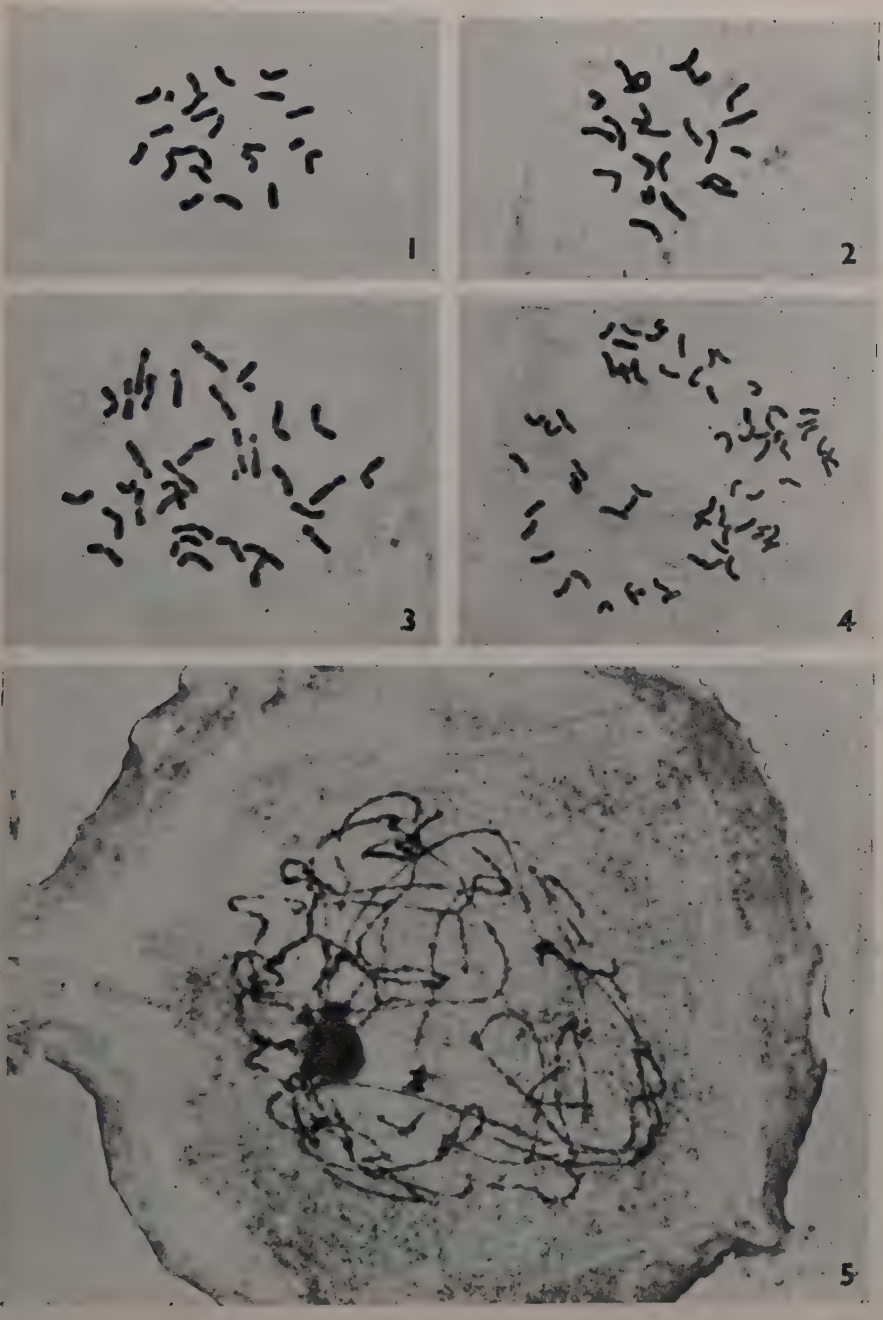
PLATE V

FIG. 6. A megaspore mother cell of the diploid *Isætes coromandelina* L. showing unpaired meiotic chromosomes, ×900.

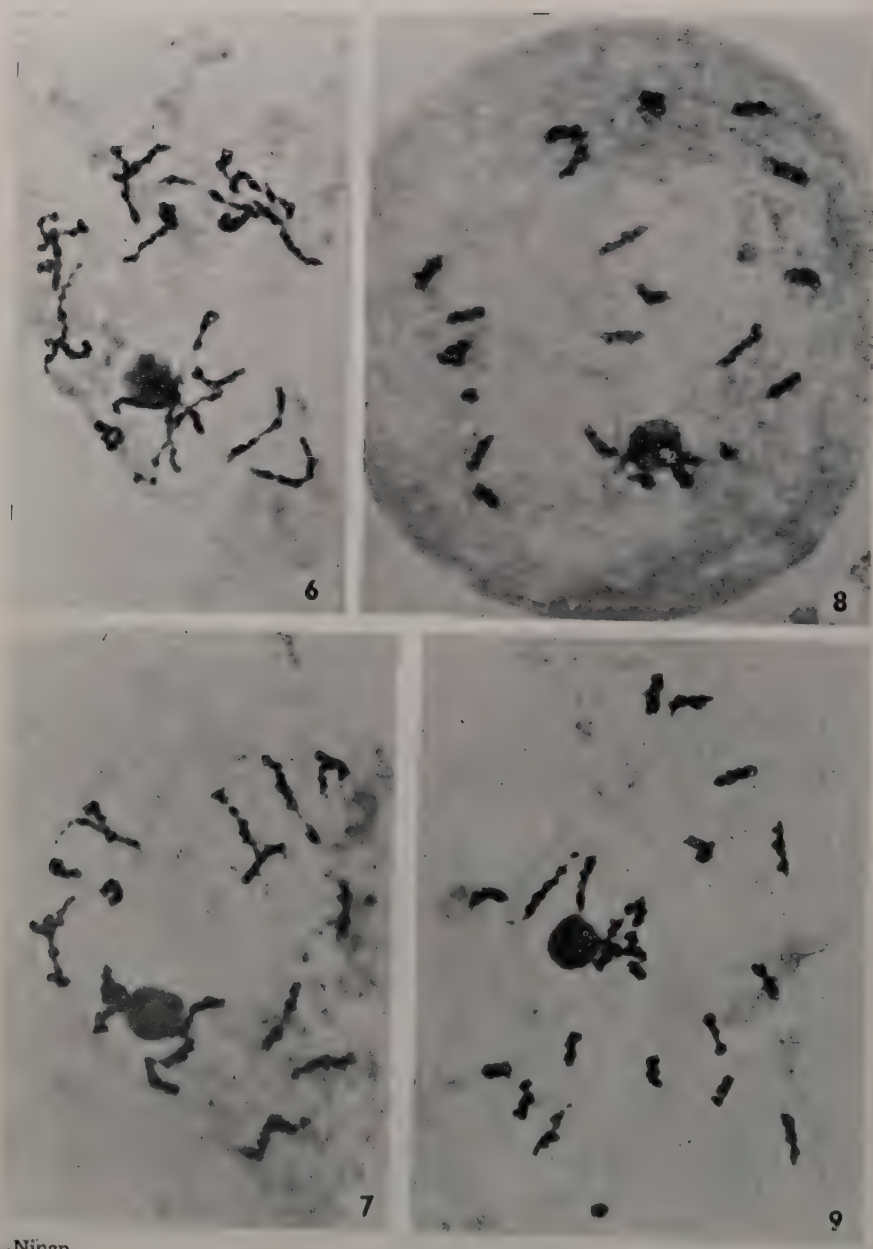
FIG. 7. A megaspore mother cell of the diploid *I. coromandelina* showing terminal and lateral associations of a few chromosomes, ×900.

FIG. 8. A megaspore mother cell of the diploid *I. coromandelina* L. showing unpaired "diplotene" chromosomes, ×900.

FIG. 9. Late "diplotene" in a megaspore mother cell of the diploid *I. coromandelina* L. showing terminal associations of a few chromosomes near the nucleolus, ×900.



C. A. Ninan



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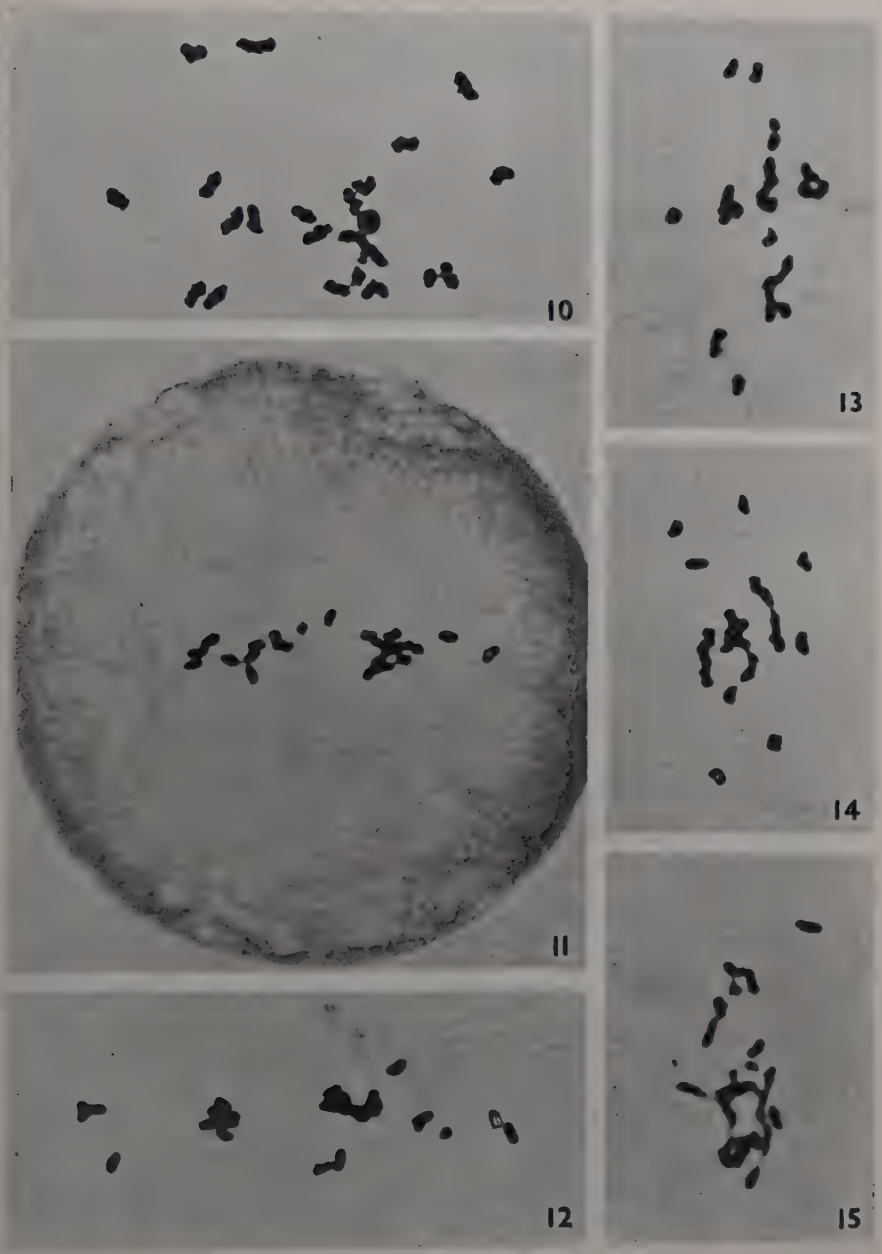

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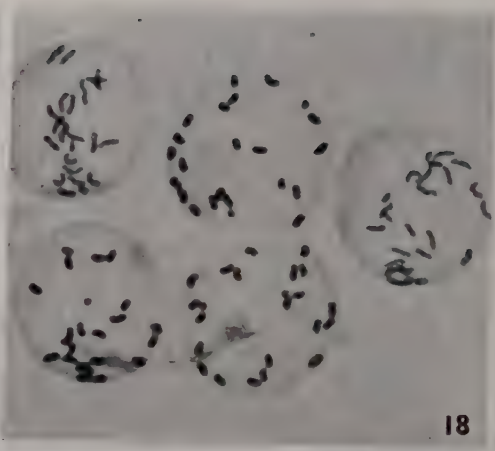
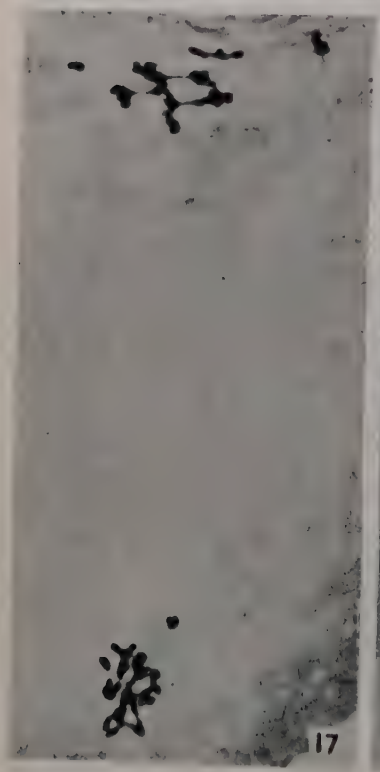
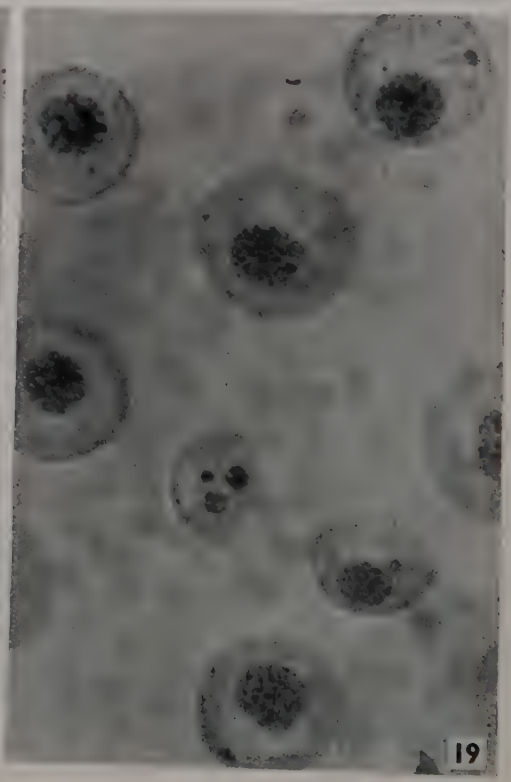
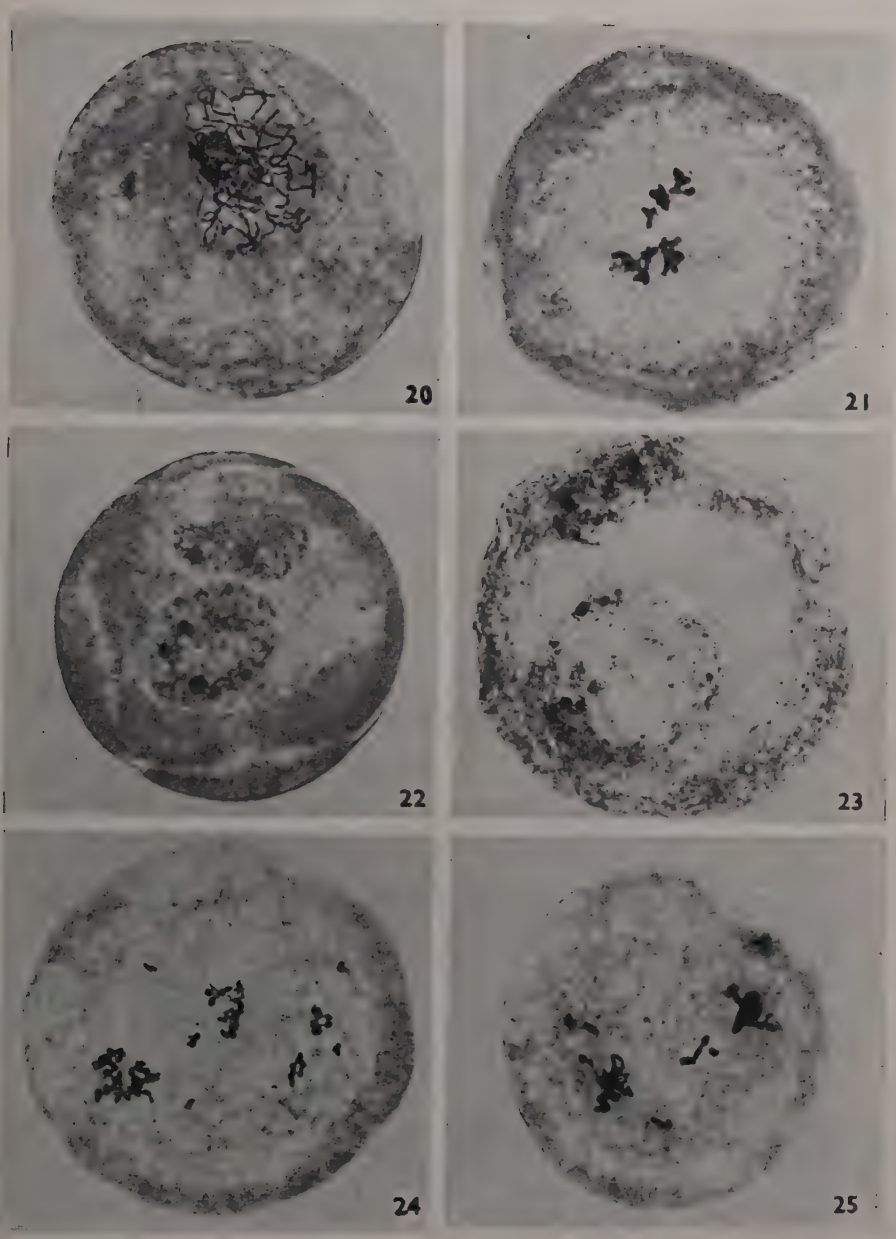






C. A. Ninan



C. A. Ninan

PLATE VI

FIG. 10. Diakinesis in a megaspore mother cell of the diploid *I. coromandelina* L. showing 23 (22 + 1) univalent chromosomes. A group of three chromosomes are seen near the nucleolus, ×900.

FIG. 11. A megaspore mother cell of the same as above showing associations of varying numbers of chromosomes. A triple chiasma is also seen at one point, ×900.

FIG. 12. Another megaspore mother cell of the diploid *I. coromandelina*. Note the cross-shaped associations of four chromosomes, ×900.

FIG. 13. A megaspore mother cell of the same as above showing lateral associations of chromosomes, ×900.

FIG. 14. Another megaspore mother cell of the same plant. Note the end to end associations of a few chromosomes, ×900.

FIG. 15. A megaspore mother cell of the same as above, showing a ring of four chromosomes and also terminal and lateral associations, ×900.

PLATE VII

FIG. 16. Anaphase I in a megaspore mother cell of the diploid *I. coromandelina* L. showing regular separation, ×1,000.

FIG. 17. Anaphase I in the same as above showing chromosome associations, ×1,000.

FIG. 18. A few microspore mother cells of the diploid *I. coromandelina* L. with 22 univalent chromosomes and a fragment, ×900.

FIG. 19. Microspores of the diploid *I. coromandelina* L. Note the variations in size and shape of the spores. Micronuclei are present in some spores, ×900.

PLATE VIII

FIG. 20. Meiotic prophase in a megaspore mother cell of the triploid *I. coromandelina*, L. ×540.

FIG. 21. A megaspore mother cell of the triploid *I. coromandelina* L. at metaphase of meiosis, showing multivalent associations, ×540.

FIGS. 22–23. Two megaspore mother cells of the triploid *I. coromandelina* L. showing two interkinetic nuclei each. Note the difference in the size of the nuclei, ×540.

FIG. 24. Irregular anaphase separation in a megaspore mother cell of the tripioid *I. coromandelina* L., ×540.

FIG. 25. Anaphase I in the same as above showing chromosome associations, ×540.

STUDIES ON THE VESSEL VARIATIONS IN DICOTYLEDONOUS TREES*

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(Received for publication on July 26, 1957)

Introduction

The problem of anatomical variations of the elements in the secondary wood of a tree trunk has long been a subject of study. The work of Sanio (1872) on the Scotspine (*Pinus sylvestris*) was the beginning of the study of variations in size and distribution of the wood elements. Similar investigations were made by Hartig (1894), Staufer (1892) and Eichhorn (1895) on different economically important timbers. Sanio (1872) observed that the tracheid at a given height in the tree increased in their length outwards from the centre for some years and then remained constant to the outside. Later investigations made on other trees show that there is an initial increase in the cell dimensions from the centre outward. But they are not able to support the theory that cells attain a constant size. Hartig and Webber (1885) found in Beech (*Fagus ferruginea*) a decrease in cell dimensions to the outside after the maximum size has been attained. Sheppard and Bailey (1914) observed the same in *Pinus palustris* and Lee and Smith (1916) in Douglas fir (*Pseudotsuga douglasii*). In the later species the results were not confirmed by Gerry (1916). Chalk (1930) has shown that the length of tracheids increases upwards to a certain height in the tree and then decreases. In the American oak (*Quercus* sp.) Eichhorn (1895) observed an increase up to the height of 16 feet and then a decrease to the top of the tree. Desch (1932) has pointed out certain features which show the least variations within the species and which in consequence are likely to afford the most reliable distinctions.

The present investigation is to show the variations in the size and configuration of the vessels at different places in certain dicotyledonous trees. The data evolved provides specific information dealing with variations in the size and arrangements of the vessels at different levels and at various portions of the same level.

Material and Method

Rendle (1944) has stated "that several closely related species of a large and widely distributed genus are identical so far as their wood structure is concerned". I have therefore selected different species of trees belonging to different genera and families for the investigation. The species selected were:

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* Taken from the Thesis "Studies on the Anatomy of South Indian Timbers," approved for the Ph.D. Degree of the University of Edinburgh in the year 1953.

(1) *Pajanelia rheedii* Wight.

(2) *Macaranga peltata* Muell Arg.

(3) *Erythrina stricta* Roxb.

(4) *Tabernæmontana dichotoma* Roxb.

(5) *Anacardium occidentale* Linn.

The same species were examined by Sebastine (1955) for studies on the variation in the structure and size of rays in the secondary wood.

Five trees of each species were selected and cut down. They were more or less of the same size collected from different localities of the same forest area. Discs of three inches in thickness were taken (1) at the bottom of the trunk one foot above the soil surface and (2) at the top of the trunk one foot below the first branching. The distance between the upper disc and the lower disc is almost the same in all the five trees of each species. In these trees growth rings are not conspicuous and in some of them the heartwood and sapwood are not to be differentiated by the naked eye or hand lens.

Blocks of wood $1\frac{1}{2}$ cm. $\times$ 1 cm. were cut at a distance of 1 inch from one aonther along the same radius from the centre to the periphery of the lower and upper discs of the five species. Thus block no. 1 was the innermost block just at the beginning of the secondary wood, and the rest were numbered in order of their position towards the outside. Cross-sections from each block were taken in the usual way and a portion of each block macerated separately for detailed study of the vessel elements. Observations were made in the following characters.

(1) The number of vessels present in 2 sq. mm.

(2) The diameter of the vessels in μ.

(3) Length of the vessel members in μ.

The vessels were observed in an area of 2 sq. mm., the number of vessels and the radial diameter of each vessel in this area were accurately counted and measured under the microscope. To obtain a fair average an area of 2 sq. mm. was noted at nine different places in the same cross-section of every block.

From the macerated tissue from each block the *total length* of the vessel member was measured from 24 different samples. The measurement was taken according to the rules laid down by Chalk & Chattaway (1932).

Results and Discussions

The data collected from the observations on the vessel distribution, diameter, and total length of vessel members, show the details of the structural variations that take place in the vessels of the secondary wood of some dicotyledonous trees from the centre to the periphery. The results of observation are recorded in the following tables.

TABLE I

Pajenelia rheedii

Lower Disc				Upper Disc			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
			Number of vessels per 2 sq. mm.				
I	7	16·25	35	I	19	30·9	43
II	5	8	12	II	13	18·3	26
III	4	6·4	12	III	7	11·3	16
IV	4	8·7	16				
V	5	8·2	12				
			Diameter of vessels				
I	44	143·9	254	I	22	107	222
II	67	201	300	II	33	167	277
III	78	192	333	III	33	186	489
IV	56	198	367				
V	67	209	356				
			Length of the vessel members				
I	322	462	567	I	167	368	567
II	111	319	478	II	133	400	666
III	278	554	844	III	267	440	556
IV	322	408	611				
V	251	408	556				

TABLE II

Macaranga peltata

Lower Disc				Upper Disc			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
			Number of vessels per 2 sq. mm.				
I	5	9·6	14	I	12	19	47
II	10	11·3	14	II	9	12·8	15
III	6	10	19	III	8	10·9	17
IV	6	10·8	24	IV	6	9·8	16
V	10	12	18	V	7	11	22
			Diameter of vessels				
I	22	175	244	I	44	134	222
II	56	174	278	II	56	182	278
III	33	177	278	III	67	209	278
IV	56	204	300	IV	56	211	222
V	44	200	311	V	56	218	911
			Length of the vessel members				
I	500	925	1233	I	556	710	1056
II	778	1032	1278	II	811	980	1333
III	311	935	1389	III	444	781	1111
IV	611	936	1155	IV	488	842	1100
V	600	955	1267	V	621	826	1111

TABLE III

Erythrina stricta

Lower Disc				Upper Disc			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
			Number of vessels per 2 sq. mm.				
I	2	4·6	9	I	2	4·9	11
II	1	3·3	6	II	3	5·2	8
III	1	3·3	5	III	1	4·3	8
IV	1	4·7	12	IV	1	4·3	7
V	1	2·9	5				
VI	1	4·6	12				
			Diameter of vessels				
I	36	253	378	I	78	206	311
II	111	258	400	II	111	233	400
III	99	284	411	III	111	256	389
IV	111	281	478	IV	133	277	335
V	111	281	422				
VI	56	280	444				
			Length of the vessel members				
I	111	272	333	I	222	261	311
II	222	308	444	II	200	248	333
III	111	265	444	III	167	252	355
IV	167	269	388	IV	167	229	278
V	111	281	422				
VI	189	280	467				

TABLE IV

Tabernæmontana dichotoma

Lower Disc				Upper Disc			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
			Number of vessels per 2 sq. mm.				
I	89	115·8	141	I	90	119·8	144
II	74	100·3	115	II	91	104·7	123
III	78	81·7	89	III	77	88·8	106
IV	72	79·9	91	IV	85	104·7	187
V	66	80·3	91				
			Diameter of vessels				
I	33	65	100	I	22	58	78
II	33	67	100	II	56	72	111
III	56	81	111	III	56	79	111
IV	67	91	111	IV	56	87	111
V	67	85	111				
			Length of the vessel members				
I	666	848	1167	I	644	881	1111
II	533	848	1167	II	6111	894	1177
III	733	900	1144	III	556	898	1222
IV	677	941	1133	IV	567	803	900
V	644	885	1111				

TABLE V

Anacardium occidentale

Lower Disc				Upper Disc			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
			Number of vessels per 2 sq. mm.				
I	8	22	59	I	11	13·8	18
II	6	10·7	14	II	5	8·1	14
III	6	6·9	8	III	5	7·3	10
IV	5	6·9	10	IV	5	8·7	13
V	6	7·1	8	V	3	7·2	12
VI	4	5·6	6				
VII	3	5·8	13				
			Diameter of vessels				
I	22	109	178	I	44	99	189
II	22	106	178	II	44	133	200
III	56	163	200	III	56	125	189
IV	44	142	222	IV	56	136	222
V	56	172	222	V	22	147	233
VI	111	157	233				
VII	73	192	333				
			Length of the vessel members				
I	256	369	500	I	244	364	444
II	222	367	500	II	244	412	500
III	244	381	556	III	222	382	446
IV	139	422	556	IV	222	414	466
V	222	414	556	V	278	373	456
VI	311	408	644				
VII	278	420	567				

It is clear that there is a tendency to reduction in the number of vessels per unit area towards the outside from the centre of the tree trunk. Block No. 1 the innermost block in all the trees shows a greater number of vessels than any other block of the same level excepting in the basal region of *M. peltata*. It is also clear from the results observed that in some cases there is a substantial difference only between the outermost and innermost block regarding this character. Thus in *P. rheedii* at the base a decrease in the number of vessels by 50% is noted in the outermost block from the innermost one. In *A. occidentale* the decrease is by 73% at the base; in *T. dichotoma* the decrease is by 31% at the base; in *E. stricta* and *M. peltata* there is no decrease. Those trees in which the vessels show a decrease towards the outside from the centre also show that there is no great difference in this respect between the outer blocks of the same radius though they do not show a constant number of vessels per unit area. On the other hand, the upper region of the tree trunk shows a remarkable decrease in the number of vessels per 2 sq. mm. towards the outside in all the five species. But here also the outer blocks do not show great differences. It is observed in these materials that though the growth rings are not conspicuous under the lens they are seen under the microscope. The vessel elements in the inner regions of the ring are found to be arranged closely and are greater in number per unit area. Blocks which have such portions of growth rings show a greater number of vessels per unit area than the other blocks. Thus in some cases the distribution of vessels per 2 sq. mm. does not show a steady decrease in number towards the outside.

A change in the mean diameter of vessels is evident from the centre to the periphery. In both the lower and the upper regions of the tree trunk the mean radial diameter shows an increase towards the outside. In some it is a steady increase.

Plates IX & X illustrate the size of the vessels in the inner block, middle block and the outermost block in the various trees. They show the largest vessel in the respective blocks. It is clear from these observations that there is an increase in the mean diameter of the vessels towards the periphery. It is also clear that the increase in the percentage of large vessels is gradual towards the outside.

The increase in the mean diameter of vessels per unit area from the centre to the outside is mainly due to the increase in the number of larger vessels formed in the outer regions towards the periphery. It is also partially due to the increase in the size of the individual vessels. This increase of the size does not continue indefinitely. There is also no absolute stability regarding radial diameter, yet it has never gone beyond certain dimensions in each species and the vessels of the maximum diameter occur in different percentage in the various outer regions of the same level in the secondary wood.

There is no clear line of changes in the total length of the vessel members in the various blocks of both lower and upper portions of the tree trunk. It is noted that in *A. occidentale* and *M. peltata* there

is an increase in the total length of the vessel members from the centre to the periphery in both lower and upper portions. In *T. dichotoma* and *E. stricta* the lower portions show an increase in the same line but the upper regions show a considerable decrease in the outermost blocks. *P. rheedii* shows a decrease in the lower disc and an increase in the upper disc.

Metcalfe and Chalk (1950) have stated that for identification the " vessel diameter is best recorded as a mean figure though varying according to position in the tree and conditions of growth ". The facts observed above clearly supports that view. But it also makes it clear that the mean diameter of vessels in different portions of the secondary wood of the same level of a tree varies considerably.

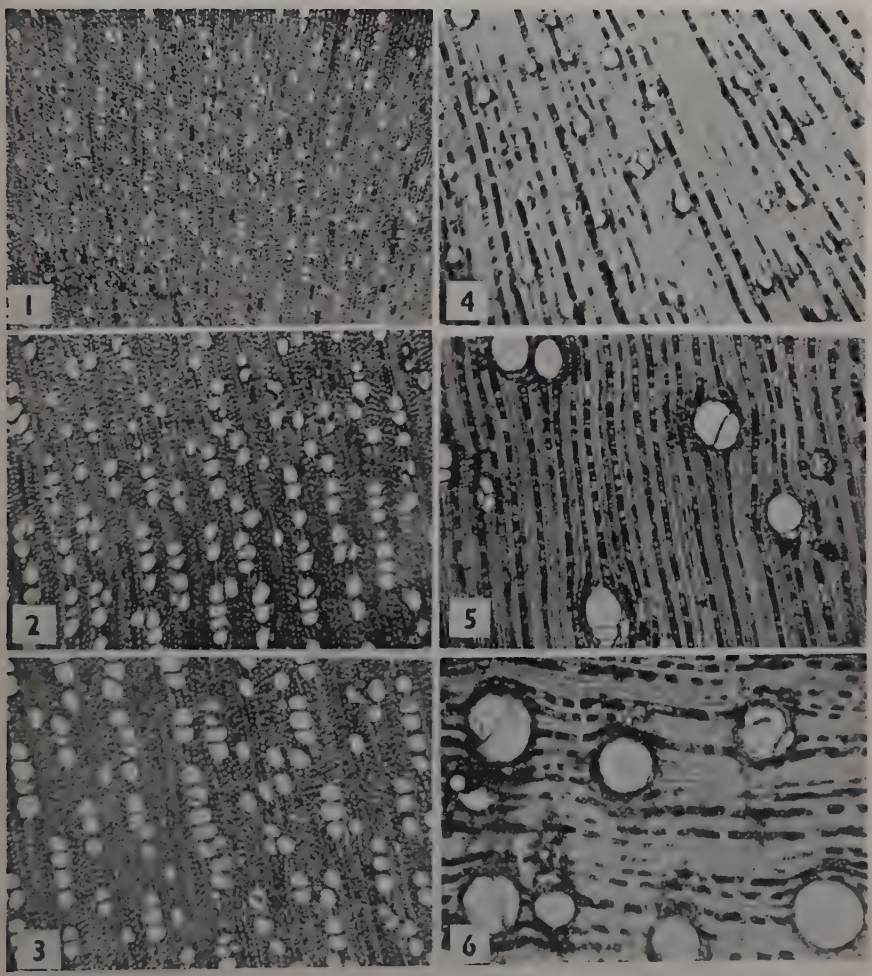
The observations made in the vessel member length also support Metcalfe and Chalk (1950) in their view " that the vessel member length in common with other cell dimensions varies considerably within any species and even in different parts of the same tree ". Bailey and Tupper (1918) have shown " that the first formed members are shorter than those developed later ". Observations made above show that in two species, *M. peltata* and *A. occidentale* the same feature occurs both in the lower and upper regions of the tree trunk. It is also true regarding the upper regions of *P. rheedii* and the lower regions of *E. stricta* and *T. dichotoma*. The lower region of *P. rheedii* show that the early formed vessel members are longer than those developed later.

Summary

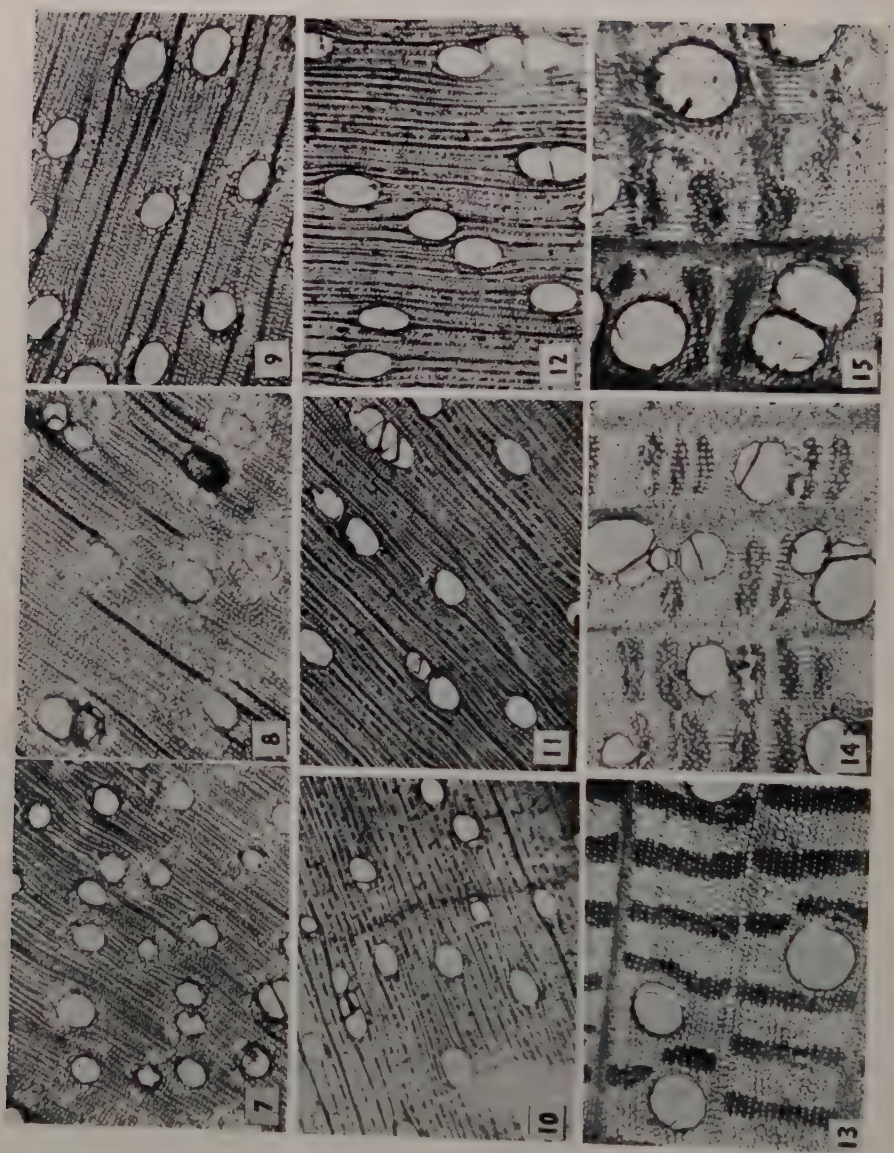
1. The mean number of vessels per unit area observed in five species of different genera and families varies at different levels and in various portions of the same level. There is a tendency towards reduction in the number of vessels per unit area from the centre of the tree to the periphery in some of the species. But this reduction is a gradual one. After a certain stage of growth no great changes in the distribution of vessels per unit area are noted in the newly formed wood. At the same time there is no constancy regarding the number of vessels formed.

2. The mean radial diameter of vessels shows an increase from the centre to the periphery. The increase in the mean diameter is mainly due to the increase in the number of larger vessels formed in the outer regions towards the periphery and also partially due to the increase in the size of the vessels. This increase in the size of the individual vessels does not continue indefinitely. There is no absolute stability regarding the radial diameter of large vessels yet it has never gone beyond certain size in each species and that maximum size occurs in different percentage in the different outer regions of the same level. Hence the mean radial diameter also varies in different portions of the same level in the secondary wood.

3. Vessel member length varies considerably in various parts of the same level and in different levels of the tree trunk in all species.



M. Sebastine



K. M. Sebastine

The author wishes to express his sincere appreciation to Mr. John Anthony and the late Professor Sir William Wright Sn ith of the Royal Botanic Garden, Edinburgh, for all help throughout the course of this work.

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Explanation for Plates

Plate IX

Figs. 1, 2 & 3. T. S. *Tabernæmontana dichotoma* (1. inner block, 2. middle block and 3. outer block), ×29.

Figs. 4, 5 & 6. T. S. *Anacardium occidentale* (4. inner block, 5. middle block and 6. outer block) ×29.

Plate X

Figs. 7, 8 & 9. T.S. *Pajanelia rheedii* (7. inner block, 8. middle block and 9. outer block), ×25.

Figs. 10, 11 & 12. T. S. *Macaranga peltata* (10. inner block, 11. middle block and 12. outer block), ×25.

Figs. 13, 14 & 15. T. S. *Erythrina stricta* (13. inner block, 14. middle block and 15. outer block), ×25.

EMBRYOLOGY OF *RHUS MYSURENSIS* HEYNE

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(Received for publication on August 19, 1957)

Introduction

The family Anacardiaceæ is economically very important for it yields products of diverse commercial interest. The edible seeds are obtained from species of *Anacardium* and *Pistacia* known as the Cashew and Pistacio nuts respectively. *Mangifera indica* is the source of mango, which is valued for its aromatic and edible flesh. Edible fruits are also obtained from species of *Spondias* and *Harpephyllum*. Resins, oils and lacquers are obtained from species of *Toxicodendron* and *Pistacia*, while species of *Schinopsis* is a source of tannic acid.

Previous literature on the embryology of this family is summarised by Schnarf (1931). Maheshwari (1934) reported a Normal type of embryo-sac in *Mangifera indica*. According to him the pollen grains are binucleate at anthesis and more than 950 endosperm nuclei are formed when the embryo consists of 3 cells. Srinivasachar (1940) investigated the embryology of *Anacardium occidentale*, *Semecarpus anacardium* and *Spondias mangifera*. He reported a Normal type of embryo-sac in all the three species and stated that the nuclear endosperm becomes cellular later. He also made some observations on the development of embryo. Copeland and Doyel (1940) gave an account of the pollen and embryo-sac development in *Toxicodendron diversiloba*. Kelkar (1954) recorded the occurrence of twin embryo-sacs in *Rhus mysurensis*. Recently Copeland (1955) described in detail the life-history of *Pistacia chinensis*. The present paper deals with an account of the development of gametophytes and embryo in *Rhus mysurensis*.

Material and Methods

The material was collected from the Law College hills, Poona. The plants begin to flower in May and produce ripe fruits and seeds by the end of August. The material was, therefore, collected at regular intervals of about a week over a period of four months. Floral buds, flowers, seeds and fruits at different stages of development were fixed in Formalin-acetic-alcohol. They were washed in 70% alcohol and later dehydrated and embedded according to the customary methods. Sections were cut 8–12 μ thick, stained in Iron-alum hæmatoxylin and destained in a saturated solution of picric acid.

Organogeny

The flower arises in the axil of a bract. The different parts of the flower arise in acropetal succession (Figs. 1 and 2) as in *Spondias mangifera* and *Semecarpus anacardium* (Srinivasachar, 1940).

Microsporangium and Microsporogenesis

The flowers are polygamous. The anthers are dithecous with longitudinal dehiscence. Each stamen receives a single vascular bundle which runs right into the connective. The stamen develops as a dome-shaped protuberance of meristematic cells. Gradually the upper part of the protuberance becomes 4-lobed.

The male archesporium differentiates in each anther lobe and consists of 3 to 4 longitudinal rows of hypodermal cells, with 20 to 25 cells in each row. It cuts off a parietal layer which in turn divides further forming three parietal layers (Figs. 3 to 5). The layer next to the epidermis develops into the fibrous endothecium (Fig. 6). Small globular yellow markings as in members of the Amaranthaceæ (Kajale, 1940) appear on the inner tangential walls of the layer, during later stages of anther development (Fig. 6). The epidermal cells also show the presence of yellow staining grains (Fig. 6). The middle wall layer degenerates during early stages of development and the innermost layer forms the tapetum of the secretory type. The tapetal cells are uninucleate to begin with. They enlarge in size in the tangential direction and become densely cytoplasmic. Later these cells become bi-nucleate as in *Semecarpus anacardium* (Srinivasachar, 1940). In this 2-nucleate condition they persist at the periphery and ultimately they degenerate as the pollen grains mature.

The primary sporogenous cells divide once and increase in number. The microspore mother cells undergo the usual meiotic divisions. Cytokinesis takes place by peripheral cleavage furrowing, and the resulting microspores are arranged in a tetrahedral manner. This is the course of development of the anther in male flowers.

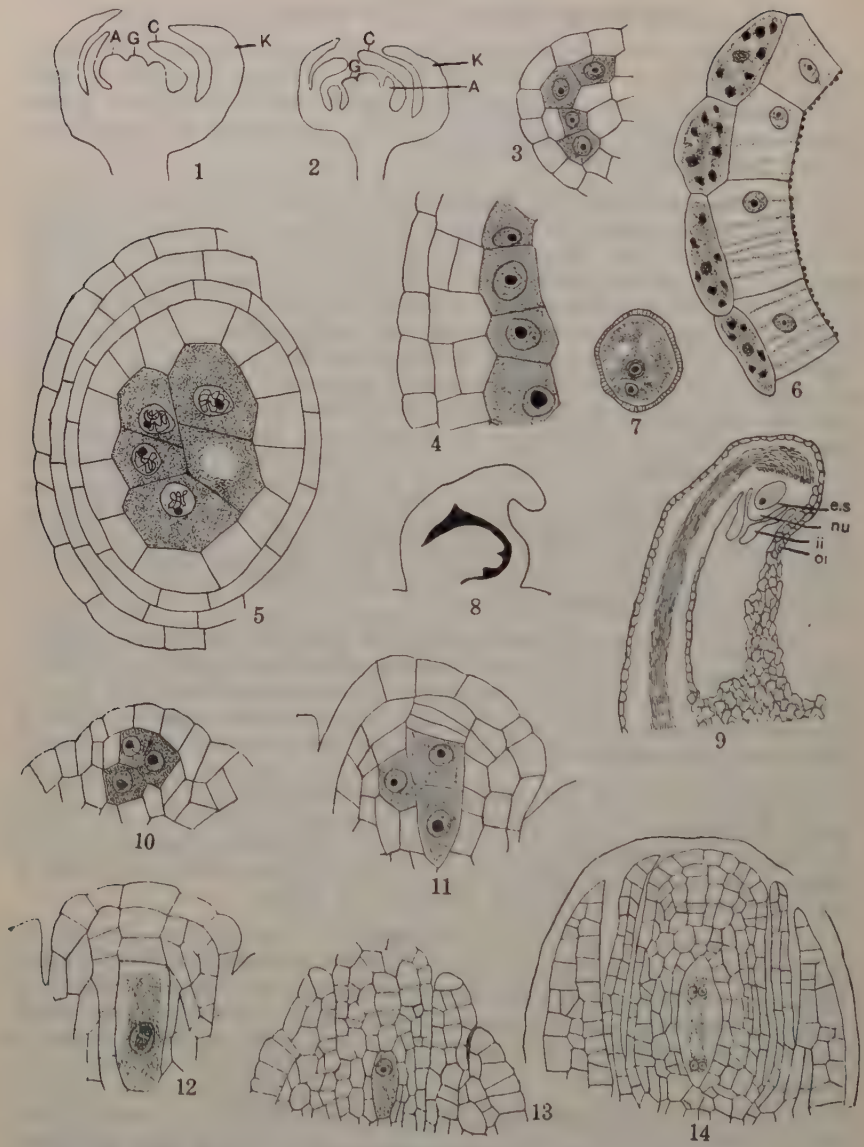
In female flowers the anther development follows the same course as in the male, up to a certain stage; later, however, the microspore mother cells degenerate. The anthers in the female flowers are thus sterile. Such stamens with sterile anthers persist till a late stage of fruit development and appear brownish in colour.

The pollen grains soon develop exine and intine. The microspore nucleus moves towards the wall where it divides to form a small lenticular generative cell and a large vegetative cell (Fig. 7). The cytoplasm in the pollen grain is dense. They are shed in this 2-celled condition and are tricolpate and spheroidal. The exine appears striated in section.

Megasporangium and Embryo-Sac

The gynœcium is tricarpellary, syncarpous and unilocular with three distinct styles. The styles and stigmas persist on mature fruit.

The ovule develops in an usual way from the base of the ovary but later it is carried up a little distance away from the base towards the style. The ovules are anatropous at the fertilization stage (Figs. 8 and 9). The structure of the funiculus is, however, peculiar. Unlike in other angiosperms it is a very robust structure from whose



TEXT-FIGS. 1–14. *Rhus mysurensis*. Figs. 1 and 2. L. S. flower-buds showing acropetal development of floral parts. *K*, Calyx; *C*, Corolla; *A*, Androecium; *G*, Gynœcium. Fig. 3. T.S. Young anther lobe showing hypodermal archesporial cells and a parietal cell. Fig. 4. Part of anther lobe in L. S. showing periclinal divisions in primary parietal layer. Fig. 5. T.S. anther lobe showing sporogenous tissue, tapetum, two wall layers, and epidermis. Fig. 6. Part of mature anther wall in T. S. showing epidermis and endothecium; note granules on inner side of endothecium. Fig. 7. 2-Celled pollen grain. Fig. 8. L. S. gynœcium showing young ovule. Fig. 9. L. S. mature ovule showing integumentary obturator and a

part of funiculus with vascular strand. *e.s*, embryo-sac, *nu*,nucellus; *ii*, inner integument; *oi*, outer integument. Fig. 10. L. S. apex of nucellus showing hypodermal and sub-hypodermal archesporial cells. Fig. 11. Three megaspore mother cells. Fig. 12. Megaspore mother cell in advanced stage. Fig. 13. L. S. ovule showing a deep-seated megaspore mother cell with well developed parietal tissue. Note splitting of integumentary primordium. Fig. 14. L. S. micropylar part of ovule showing 4-nucleate embryo-sac and two integuments arising due to splitting.

Fig. 1, ×60; Fig. 2, ×55; Figs. 3, 5, 7, 10, 11, 12, × 450. Fig. 4, × 1,070; Fig. 6, ×500; Fig. 8, ×50; Fig. 9, ×30; Fig. 13, ×300. Fig. 14, ×220.

upper end the main body of the ovule hangs down (Fig. 9). The ovule is bitegmic unlike that of *Pistacia chinensis* (Copeland, 1955) where it is unitegmic. The outer integument originates due to splitting of the single integument during the early stages of development. This is an interesting point in the development of the two integuments in *Rhus mysurensis*. As development proceeds the split between the two integuments extends towards the chalaza. At the 4-nucleate embryo-sac stage the split extends to about two-thirds the entire length of the integument while in the lower one-third region no split is seen (Fig. 14). Later the split develops up to the chalazal region. Further the outer integument during post-fertilization stages grows forming a long flap-like covering of the ovule (Fig. 9). The cells in this region become elongated and form a tissue of loose cells which may or may not fuse with a part of the funiculus. This may be described as integumentary obturator. Such an unusual behaviour of the integument is probably correlated with its method of origin. Copeland (1955) has described the presence of obturator in *Pistacia chinensis* but according to him it develops from the base of funiculus.

The archesporium in the ovule consists of 3–4 hypodermal and sub-hypodermal cells. It cuts off a parietal cell as in *Spondias purpurea* (Juliano, 1932) and *S. mangifera* (Srinivasachar, 1940). Occasionally two archesporial cells develop up to the megaspore mother cell stage (Fig. 11). The archesporium in *Rhus toxicodendron* (Grimm, 1912) functions directly as the megaspore mother cell but this observation requires confirmation. The parietal cell by further anticlinal and periclinal divisions forms a massive perietal tissue as a result of which the megaspore mother cell becomes deep seated (Fig. 13) as in *Toxicodendron diversiloba* (Copeland and Doyel, 1940).

The megaspore mother cell undergoes two meiotic divisions forming a linear tetrad of megaspores (Fig. 15). One of them on the chalazal side gives rise to the embryo-sac, while the other three degenerate. The nucleus of the functional megaspore undergoes three successive divisions forming an 8-nucleate embryo-sac (Fig. 17) of the Normal type as reported by Grimm (1912), Copeland and Doyel (1940), Copeland (1955) and Srinivasachar (1940) for other members of the Anacardiaceæ.

A case of an inverted T-shaped tetrad was noted (Fig. 16). The micropylar megaspore of this tetrad was degenerating. The chalazal megaspore on the right and the second from the micropylar end showed signs of further development. Both these were bigger than the other two and the second megaspore showed two neclei.

The 3 nuclei at the micropylar end develop into the egg apparatus. The synergids are hooked and have chalazal vacuole (Figs. 18 and 19). Sometimes they were egg-like (Fig. 17). The egg is flask-shaped with vacuole at the micropylar end and nucleus at the base (Fig. 17). The antipodals are three ephemeral cells. The polar nuclei fuse in the upper half of the embryo-sac to form the secondary nucleus. The mature embryo-sac may be cylindrical in shape or about two-thirds of its micropylar part may become dilated (Figs. 17 and 18).

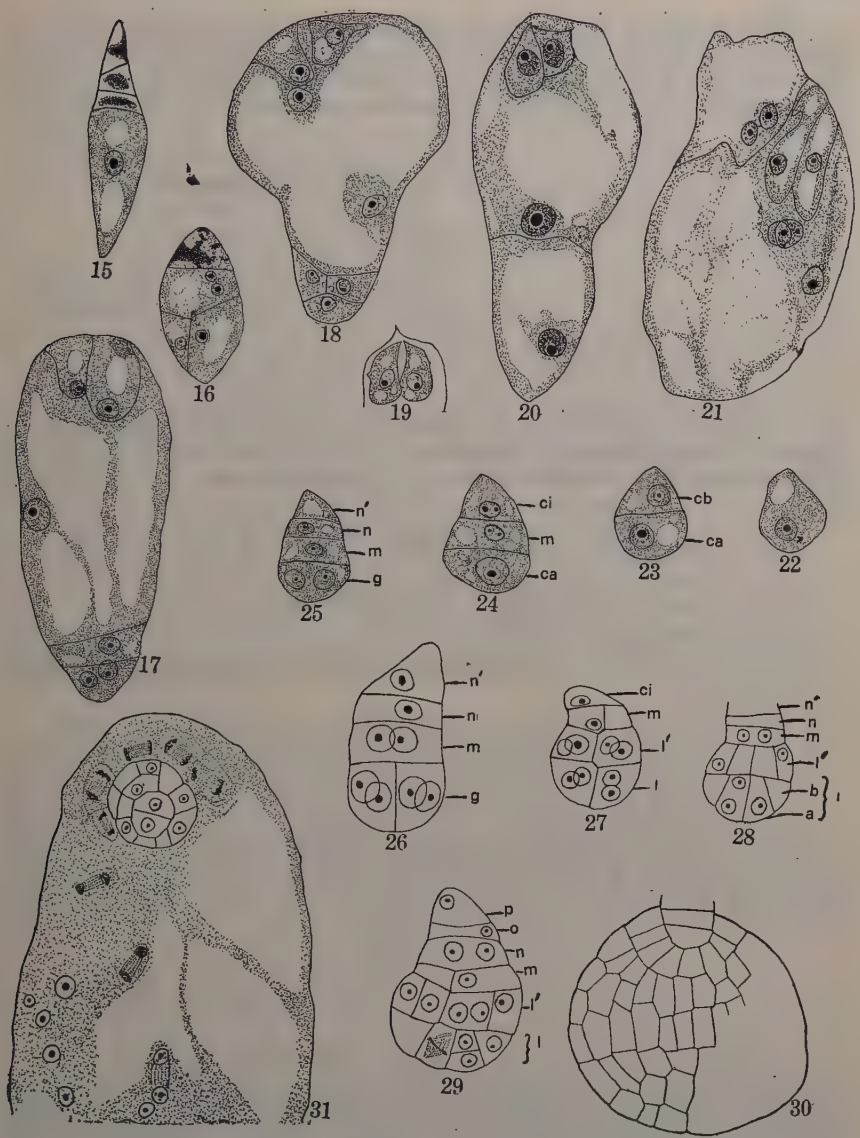
Two cases of abnormal embryo-sacs were observed. In Fig. 20 the upper embryo-sac appeared to have developed from the third megaspore and showed 3 nuclei. Of these, the two nuclei at the micropylar end had organized into an egg and a hooked synergid. The third nucleus was situated at the chalazal end. The lower embryo-sac had only one nucleus. The upper embryo-sac in Fig. 21 had two nuclei at its chalazal end. The lower one was 5-nucleate and showed towards the micropylar end a hooked synergid, another synergid, two closely pressed polars and an antipodal nucleus in the middle towards one side of the embryo-sac.

Endosperm

The endosperm nucleus divides in a free nuclear manner and forms 16 nuclei when the egg divides transversely. The early divisions of the nuclei are simultaneous and these are placed towards the periphery. Though the division of these nuclei during earlier stages is simultaneous, there is no strict synchronisation of the nuclear divisions later and nuclei in different stages of development are seen in the embryo-sac (Fig. 31). In *Mangifera indica* (Maheshwari, 1934) as many as 950 nuclei are formed at the 3-celled stage of the embryo. The nuclear endosperm becomes cellular later as the cotyledons are differentiated.

Embryo

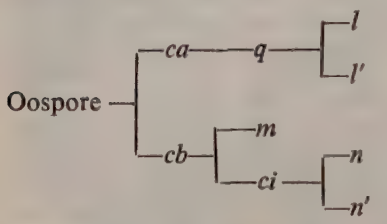
The first division of the zygote (Fig. 22) is transverse resulting in the terminal cell *ca* and the basal cell *cb* (Fig. 23). The next division in *cb* is again transverse forming the cells *m* and *ci* (Fig. 24). Thus a filament of 3 cells is organized. Now a first vertical wall is laid down in cell *ca* to form two juxtaposed cells *q* (Fig. 25). Thus a ⊥-shaped proembryo disposed in three tiers is formed. The apical tier consists of 2 cells while the other two consist of one cell each. Sometimes, however, the cell *ci* divides transversely forming the cells *n* and *n'* when the first vertical wall appears in tier *ca* (Fig. 25). Both the cells constituting *q* divide vertically once again at right angles to the first resulting in a quadrant stage (Fig. 26). At this stage the embryo generally consists of 6, sometimes 7 or rarely 8 cells, disposed in 3 or 4 tiers as in the Euphorbia variation of the Onagrad type (Johansen, 1950). Each cell of the quadrant divides further in a transverse plane leading to the formation of an octant consisting of two tiers of four cells each designated as *l* and *l'* (Fig. 27). Tier *l* ultimately develops into the cotyledons and stem tip, and *l'* produces the hypocotyl.



TEXT-FIGS. 15–31. *Rhus mysurensis.* Fig. 15. Linear tetrad. Fig. 16. Inverted T-shaped tetrad. Fig. 17. Mature embryo-sac showing an egg, a synergid, a secondary nucleus and 3 antipodals. Fig. 18. Embryo-sac showing an egg, hooked synergid, polars and antipodal cells. Note the dilated micropylar part of the embryo-sac. Fig. 19. Hooked synergids. Figs. 20 and 21. Abnormal embryo-sacs (for explanation see text). Fig. 22. Fertilized egg. Figs. 23–30. Stages in development of embryo. Fig. 31. Micropylar part of the embryo-sac showing nuclear divisions in endosperm.

Figs. 15 to 22, ×450; Figs. 23 to 26, ×700; Figs. 27 to 30, ×500; Fig. 31, ×320.

Cell *m* derived from the cell *cb* completes the root tip. The remaining cells *n*, *n'* and their derivatives give rise to a short, uniseriate suspensor which is seen during late stages of embryo development. The origin of the different parts of the embryo is shown in the following scheme.



Stem tip and cotyledons.

Hypocotyl and radicle.

Hypophysis (root tip and root cap).

Suspensor.

The origin, disposition, eventual destination and histogenic functions of the proembryo cells during the four successive generations in *Rhus mysurensis* is tabulated below. Abbreviations are after Johansen (1950).

1*st cell generation*.—The proembryo consists of two cells only.

$$ca = pco + pvt + phy + ice.$$
$$cb = iec + co + s.$$

2*nd cell generation*.—The proembryo consists of four cells disposed in three tiers.

$$q = pco + pvt + phy + ice.$$
$$m = iec + co.$$
$$ci = s.$$

3*rd cell generation*.—The embryo consists of six or seven cells disposed generally in three tiers. Sometimes the cell *ci* divides transversely and the embryo then consists of eight cells disposed in four tiers.

$$q = pco + pvt + phy + ice.$$
$$m = iec + co.$$
$$\left.\begin{matrix} n \\ n' \end{matrix}\right\} = s.$$

4*th cell generation*.—The embryo consists of eleven cells disposed in four tiers or of twelve cells disposed in five tiers. Tier *q* at this stage divides transversely and forms eignt cells four in each of the tiers *l* and *l'*. Tier *m* consists of 2 cells.

$$l = pco + pvt.$$
$$l' = phy + ice.$$
$$m = iec + co.$$
$$\left.\begin{matrix} n \\ n' \end{matrix}\right\} = s.$$

Further development proceeds as follows: Tier *l* consists of 4 cells. Each one of the cells divides by oblique walls as shown in Fig. 28 cutting off four outer cells (*b*) and four inner cells (*a*). These cells later divide in periclinal fashion and cut off the dermatogen (Fig. 29). This happens slightly after the dermatogen has become differentiated in the tier *l'*. After the completion of the dermatogen in a basipetal order, tier *l* divides mostly by vertical walls as a result of which the embryonal mass enlarges in its circumference (Fig. 30). The cells in the centre ultimately form the plumule, while those at the preiphery present in two groups, one on either side of the plumule, form the cotyledons.

Simultaneously with the changes in the tier *l* the cells of the tier *l'* also divide longitudinally and transversely and form the hypocotyl and radicle. The dermatogen, as stated before, appears first in this tier and is later completed in the tier *l*. Tier *m* which functions as hypophysis consists of a single cell to begin with. It divides first by vertical wall (Figs. 27 to 29). This is soon followed by another vertical division and four cells are formed. These then divide periclinally. While cells cut off on the outer side form the root cap those on the inner side contribute to the two histogenic layers of the radicle.

Tiers *n* and *n'* are derived from *ci*. There is no fixed course regarding the formation of these two tiers. Sometimes it divides before or after the octants are formed (Figs. 26 and 27). Tier *n'* may divide again transversely forming cells *o* and *p* and these constitute an uniseriate suspensor of few cells.

Thus the embryogeny of *Rhus mysurensis* agrees closely with the Euphorbia variation of the Onagrad type (Johansen, 1950) or the Crucifer type (Maheshwari, 1950). A similar course of embryo development is noticed (Johansen, 1950) in *Semecarpus anacardium*. In *Anacardium occidentale*, however, the development of the embryo follows a very different course, namely, the Penæa variation of the Asterad type.

Summary

The paper deals with the development of gametophytes and embryo in *Rhus mysurensis* Heyne.

The male archesporium consists of 3 to 4 rows of cells. The parietal cells are cut off. The anther wall consists of an epidermis, a fibrous endothecium, a middle layer which soon degenerates and the secretory tapetum. The epidermal cells contain numerous tannin grains. Cytokinesis is by furrowing. The pollen grains are tricolpate. They are 2-celled at anthesis.

The ovules are crassinucellate and bitegmic. The outer integument originates due to the splitting of a single primordium. It forms a flap-like structure forming an integumentary obturator.

The female archesporium is multicellular but only one cell develops further. A linear tetrad of megaspores is formed. The chalazal

megaspore develops into an 8-nucleate embryo-sac of the Normal type. Antipodals are short-lived. Twin embryo-sacs are sometimes observed.

The nuclear endosperm becomes cellular later.

The proembryo consists of 4 cells and is ⊥-shaped. Embryo development conforms to the Euphorbia variation of the Onagrad type.

Acknowledgements

The author wishes to express his sincere thanks to Dr. L. B. Kajale, Principal, Science College, Nagpur, for guidance and helpful criticism. Sincere thanks are also due to Dr. D. V. Bal, Director, Institute of Science, Bombay, for his kind interest in the work. The author is thankful to Dr. S. P. Agharkar for providing facilities in the M.A.C.S. Laboratory, Poona, where a part of this work was done and to Dr. A. C. Joshi and Prof. (Mrs.) E. Gonzalves for valuable help and encouragement.

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STUDY OF VELAMEN IN SOME EPIPHYTIC AND TERRESTRIAL ORCHIDS

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(Received for publication on February 16, 1957)

Introduction

In spite of velamen being first recognised in the Orchidaceæ, it has seldom received the attention of workers in anatomy for intensive study of its ontogeny and morphology. Göebel (1922) reviewed the earlier literature on velamen pertaining to physiological aspect. Later, Engard (1944) gave a critical summary ot work done on the morphology of this tissue. Recently, Lakshminarayana and Venkateswarlu (1950) and Narayana Swami (1950) reported velamen in terrestrial orchids *Eulophia graminea* R. Br. and *Spiranthes australis* Lindl. respectively. Mulay and Deshpande (1952) studied velamen in *Asparagus*. Sakharama Rao (1953) observed velamen in *Phajus wallichi* Lindl. Deshpande (1955) reported velamen in some members of the Liliaceæ and Amaryllidaceæ. Mulay *et al.* (1956 *a*, *b*, *c*) investigated ontogeny and morphology of velamen in some terrestrial orchids.

Materials and Methods

In the present work three epiphytic orchids, namely, *Epidendrum radicans* Pav. ex. Lindl., *Cœlogyne barbata* Lindl. ex. Griff., *Eria nana* A. Rich. and one terrestrial species, *Calanthe veitchi* Hort., were studied. The roots of epiphytic orchids were obtained from Ootacamund and of the terrestrial orchid from Trivandrum.

Usual procedures of dehydration and embedding were followed. Microtome and freehand sections were taken. Safranin, fast green and iron hæmatoxylin were used as stains.

Observations

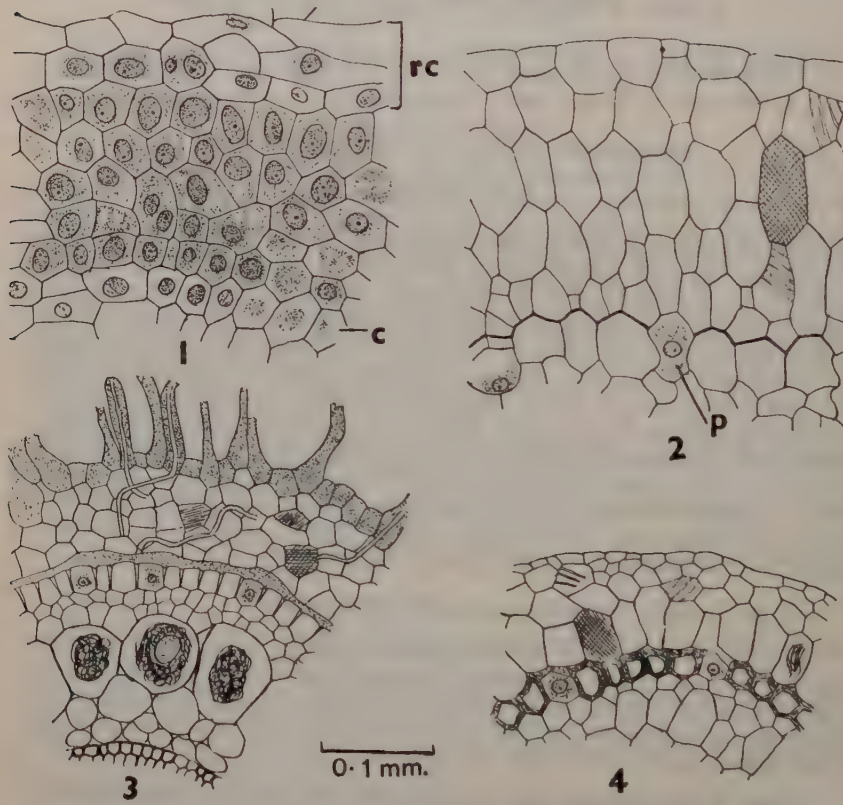
Ontogeny of Velamen

Velamen in all the species studied originates from the protoderm. For quite a considerable distance from the root apex protoderm is surrounded by extension of root cap tissue. This begins to disappear at the level where protoderm cells begin to show vacuolation (Fig. 1). In the region, at the apex where nuclei have been lost from the velamen cells, feeble thickening bands begin to appear on their cell walls.

Internal Features

Velamen is five to six layers deep in *Epidendrum radicans* (Fig. 2) and *Cœlogyne barbata* (Fig. 3) while in *Eria nana* and *Calanthe veitchi*

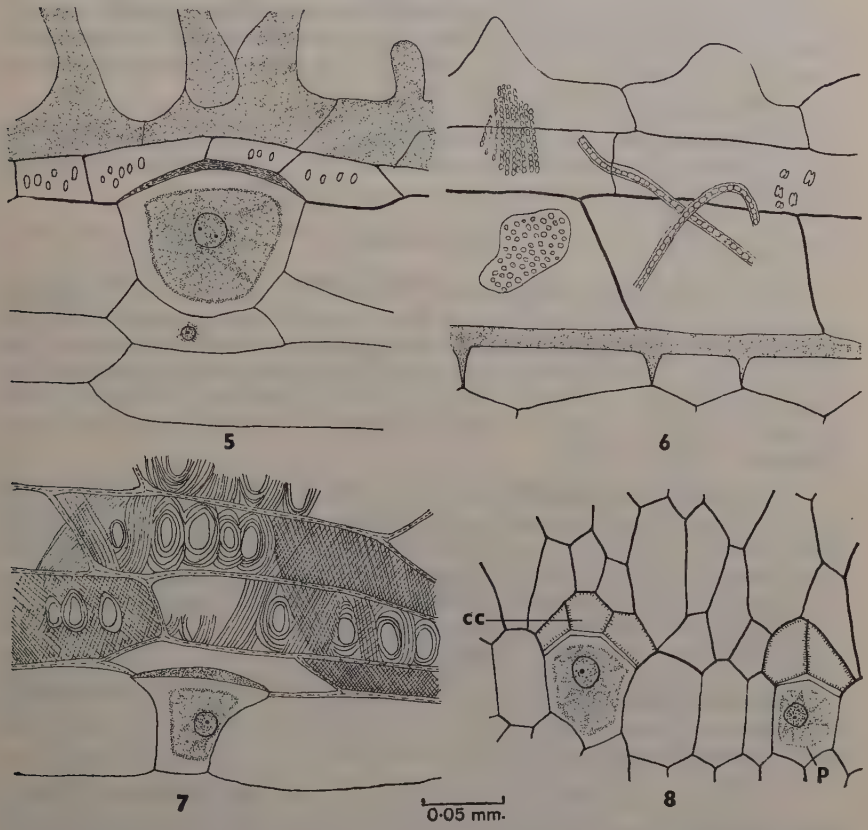
it is 3 to 4 and 2 to 3 layers respectively (Figs. 4 and 5). Velamen has both isodiametric and radially elongated cells. Some cells are tangentially flattened. Some cells in the outermost layer of velamen in



FIGS. 1–4. Fig. 1. Early stage of velamen. The outermost layer is surrounded by cap tissue. *rc*, root cap; *c*, cortex. Fig. 2. Portion of root of *Epidendrum radicans* in *t.s.* showing velamen and exodermis. A few cells with thickening bands are seen. *p*, passage cell. Fig. 3. Portion of root of *Cœlogyne barbata* in *t.s.* showing velamen, exodermis and digestion cells of cortex. Fungal hyphæ are seen entering through root hairs. Fig. 4. Portion of root of *Eria nana* in *t.s.* showing velamen, exodermis and a few layers of cortex.

Cœlogyne and *Eria* are protuberent (Fig. 6) and are generally stubby in nature but sometimes long and slender. In all the species tangential and radial walls of the velamen cells are uniformly thick and the walls possess fine thickening bands. Velamen of *Epidendrum* and *Cœlogyne* in polarised light reveal thickenings clearly. Banded thickenings in *Calanthe veitchi* are not so well pronounced as they are in three epiphytic species, *viz.*, *Epidendrum*, *Cœlogyne* and *Eria*. Pits also occur on the walls of velamen cells of *Calanthe veitchi* (Fig. 5). In longitudinal sections velamen cells appear excessively elongated along the

axis of the root in *Epidendrum radicans*, *Cœlogyne barbata* and *Calanthe veitchi*. In *Eria nana* cells in the first two layers of velamen are elongate while those in the subsequent layer are not so long as in the first two layers (Fig. 6). In *Epidendrum radicans* the thickening bands coil in such a way as to leave big pits (Fig. 7).



FIGS. 5–8. Fig. 5. Portion of root of *Calanthe veitchi* in *l.s.* showing two-layered velamen. Pits are seen. Fig. 6. Portion of root of *Eria nana* in *l.s.* showing velamen and exodermis. *Nostoc* and *Oscillatoria* colonies are seen. Fig. 7. Portion of root of *Epidendrum radicans* in *l.s.* showing banded thickenings. Fig. 8. Portion of root of *Epidendrum radicans* in *t.s.* showing cover cells over the passage cells. *cc*, cover cells; *p*, passage cell.

Delimiting the velamen from cortex is the special layer exodermis. This layer is constituted of long " exodermal cells " and short " passage cells ", which feature can be easily made out in longitudinal sections. The outer tangential walls or the exodermal cells are usually thick while those of passage cells are thin; however, sometimes passage cells also possess thick outer tangential walls. Radial walls of both are thick tapering towards the cortex. Occasionally cover cells are present over some of the passage cells (Fig. 8) as in *Epidendrum radicans*. Pits also

occur on the walls of some exodermal cells of *Cœlogyne barbata*. Fibrous matter is present on the outer tangential wall of the exodermal layer in *Cœlogyne* and *Eria* forming fibrous pads.

Mycorrhizal fungus is abundant in all the species. Hyphæ enter velamen through root hairs and then pass through the passage cells into the cortex where they coil up to form wefts. In the middle cortical layers they are digested and reduced to brown clots. In *Cœlogyne* and *Eria* there are two special rows of large cells in the cortex where digestion of fungal hyphæ is effected (Fig. 3).

A characteristic feature observed only in the case of *Eria nana* is the presence of certain blue green algæ like *Oscillatoria* and *Nostoc* of which the latter is in much greater proportion (Fig. 6).

Discussion

The present study reveals that velamen is the product of the protoderm. From the observations of the epiphytic and terrestrial species studied, the general characteristic of epiphytic velamen is found to be the presence of fine fibrillar thickenings and presence of big pits, while terrestrial velamen cell-walls were found to be pitted. However, there cannot be drawn a hard and fast line between epiphytic and terrestrial velamen in this respect.

Root hairs are generally believed to be present in terrestrial plants only. A significant feature in the present investigation was the presence of root hairs in two epiphytic orchids, *Cœlogyne barbata* and *Eria nana* while the third *Epidendrum radicans* was devoid of them. In *Cœlogyne* root hairs are long and numerous and fungal hyphæ enter through them. In *Eria* they are comparatively less in number and are remarkable in their short stubby nature.

Special features observed in the exodermis include the occurrence of more than one passage cell in a group and presence of transverse marks and pits on the exodermal cell-walls.

A striking similarity was observed in the structure of exodermis and endodermis. Both form limiting layers on either side of the cortex and allow the passage of water only through the passage cells. The passage cells in both the layers have nuclei and cytoplasm. Even in ontogeny both exodermis and endodermis originate from cortically initiated zones. The outer tangential walls of the exodermis are thick while the inner tangential walls are thick in case of endodermis. In both cases radial walls which are also thick, taper towards the cortex. As already suggested by Van Fleet (1950) exodermis may be regarded as a mirror-image of endodermis.

The above facts show that velamen in epiphytic and terrestrial plants is almost similar and differences are minor ones and of details only. It is difficult to attribute any definite function to velamen and views on this issue are varied. Some workers are of the opinion that it serves for protection and absorption of moisture in epiphytes.

Others postulate that it is just a vestige basing their conclusion on study of terrestrial velamen. However definite conclusions cannot be drawn as only a few plants have been investigated so far.

Summary

1. The present work deals with a study of the ontogeny and morphology of velamen and exodermis in three epiphytic and one terrestrial species of Orchidaceæ.

2. Velamen is protodermal in origin and structural modifications of epiphytic velamen and terrestrial velamen are similar, difference being of details only.

3. Exodermis develops from cortical zone and has uniform features in all the species. It resembles endodermis in ontogeny and morphology.

4. Special cortical digestive cells occur for the digestion of fungal hyphæ.

5. Presence of various algæ, especially belonging to Cyanophyceæ, has been observed in velamen of *Eria nana*.

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PALMOXYLON PURATANUM, A NEW SPECIES OF PETRIFIED PALMS FROM THE TERTIARY ROCKS OF SOUTH ARCOT DISTRICT, MADRAS

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(Received for publication on November 16, 1957)

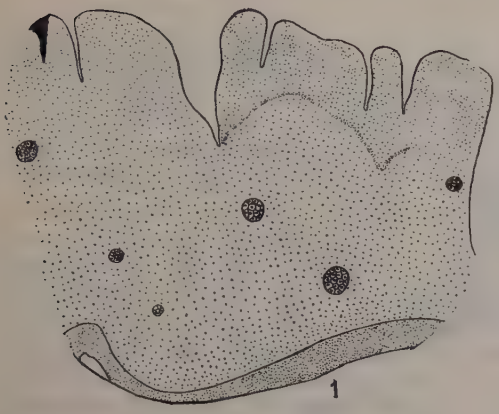
Introduction

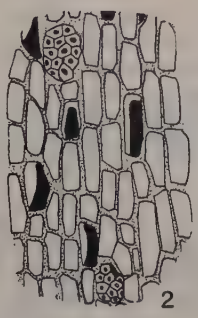
The present communication deals with a new species of fairly well preserved petrified palm stems from the Cuddalore sandstones (Miocene) of South Arcot District. The species is represented by a single, highly silicified and partly weathered, medium-sized specimen collected from Mortandra, 5 miles N.-W. of Pondicherry. Remains of fossil palms are rather few and far between in the Tertiary rocks of South Arcot district, which abundantly contain numerous petrified woods of dicotyledonous and coniferous affinities (Ramanujam, 1953 *b*, 1954 *a*, 1954 *b*). It was in 1931 that Sahni for the first time gave a cursory description of a silicified palm stem, *Palmoxylon pondicherriense* from the Tertiary rocks of South Arcot district, but unfortunately the exact locality from where this species was collected is not known. A few years later another palm stem was described from this area; this more or less resembles the extant species of *Livistona* (Ramanujam, 1953 *a*). The present species, thus, forms the third one from the same area. The flora so far described from these rocks is predominantly dicotyledonous with a sprinkling of palms and conifers and seems to be distinctly tropical in its nature.

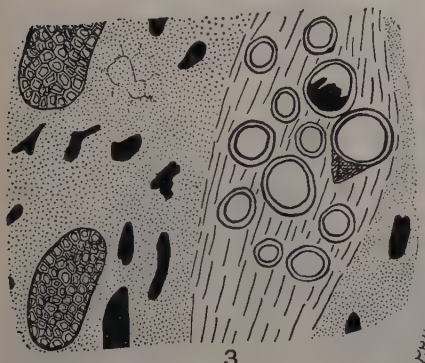
Description

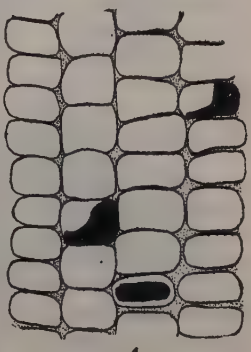
The fossil is rusty brown and 10×15 cm.; its broad peripheral arc indicates that it might have been chipped off from a stump of considerable girth. The stem proper is encased externally by a felt of leaf-sheaths which show quite a number of longitudinal cracks, a state of affairs not uncommonly met with in the modern palm stems (Text-Fig. 1; Pl. XI, Fig. 1). In cross-section the epidermis of the leaf-sheaths is well defined but the cells are rather irregularly arranged. The cells are either empty or plugged with a dark coloured deposit, which either completely fills the cell or forms a somewhat thick parietal layer. Following the epidermis, the body proper of the leaf-sheath consists of rather closely packed angular parenchyma cells. Scattered among these, there are numerous fibrous bundles of various sizes. On an average the bundles consist of 12–16 fibres (Text-Fig. 2; Pl. XI, Fig. 3).

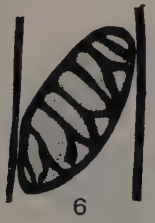
Cortex.—Internal to the leaf-sheath region is the meagrely developed cortex. The ground tissue of the cortical region is imperfectly preserved











TEXT-FIGS. 1–6. *Palmoxylon puratanum* sp. nov. Fig. 1. Part of the leaf-sheath region (semi-diagrammatic) showing the fibrous bundles, ×10. Fig. 2. Cells of the leaf sheath region enlarged to show the details, ×320. Fig. 3. Part of the cortical zone to show the dark deposits and a leaf trace bundle, ×320. Fig. 4. Ground parenchyma as seen in longitudinal section, ×320. Fig. 5. A Leaf trace bundle from the central zone surrounded by radiating parenchyma, ×320. Fig. 6. Oblique sclerenchyma perforation plate of a xylem vessel, ×320.

and only here and there do we come across some very thin-walled parenchyma cells. In this badly preserved tissue there are numerous solid dark deposits the nature of which is unknown (Text-Fig. 3; Pl. XI, Fig. 4). Scattered in the cortex are numerous purely fibrous bundles of various shapes and sizes. As a rule, these bundles are circular to

oval in cross-section, about 60–140 μ in diameter and consist of 15–40 fibres. There are no stegmata around these bundles. There are, however, some structures which in section superficially look like fibrous bundles, but are devoid of any cellular structure within. These may represent scleroids or mucilage canals. The cortex at places is traversed by leaf traces cut obliquely. Normal fibrovascular bundles are also present in the cortical zone but they are very few and sporadic.

Dermal zone.—This consists of numerous normally oriented fibrovascular bundles, closely packed leaving little or no ground tissue in-between (Text-Fig. 7; Pl. XI, Fig. 2; Pl. XII, Fig. 5). The average frequency of the bundles is 80–100 per cm.^{2}, but in the extreme periphery it is 140–165 per cm.^{2} The bundles by their contiguous nature become compressed at many places and thus are of varying forms. In general these bundles are elliptical and $0{\cdot}8 \times 0{\cdot}5$ mm. The fibrovascular ratio (f/v) is about 4/1. The bundles of the outer two rows are extremely small with equal proportions of xylem and sclerenchyma. The median sinus of the fibrovascular bundles is rounded cordate. In each bundle there is a large vessel excluded from the sinus. There are no purely fibrous bundles in this zone.

Subdermal zone.—This is fairly well developed. The fibrovascular bundles are more sparsely distributed than those of the preceding zone, being only 65–75 per cm.^{2} They are mostly separate from each other and thus become undistorted (Text-Fig. 8; Pl. XI, Fig. 6). As a rule, the bundles are normally oriented; the average diameter of the bundles as seen in the cross-section is 1·3–1·5 mm. Their outline is generally elliptical or broadly oval. The dorsal facet of the sclerenchyma sheath is elliptic or somewhat uniformly hemispherical and its base is more or less cordate; but here and there we also come across bundles in which the median sinus is somewhat reniform (Text-Fig. 8). The f/v ratio of these bundles is 3/2 to $1\frac{1}{2}$/1.

Tabular parenchyma is very commonly present and usually two-layered. Auricular sinuses are insignificant as the auricular lobes merge insensibly and gradually into the sides of the xylem. Median sinus, however, is quite sharply defined in almost all the bundles. Phloem wedged in this sinus is poorly preserved and seen as small, angular, thin-walled and broken cells. The xylem consists of mostly a pair of metaxylem vessels placed side by side and excluded from the median sinus and 1–3 small protoxylem elements internal to them. The sculpturing of the vessels is similar to that of the corresponding structures seen in the central zone and described below.

There are no structures comparable to stegmata in association with the fibrovascular bundles. Further, purely fibrous bundles are also absent in the subdermal zone.

Central zone.—This can easily be distinguished from the above two zones by the nature and distribution of the fibrovascular bundles and the general pattern of the ground tissue. This part is not completely preserved in the present fossil specimen. The fibrovascular bundles here lie far apart being only 20–25 per cm.^{2}, and the ground

TEXT-FIGS. 7–12. *Palmoxylon compactum* sp. nov. Fig. 7. Form and distribution of the fibrovascular bundles in the dermal zone. Sclerenchyma black, xylem parenchyma dotted, pholoem left unshaded, ×55. Fig. 8. Form and distribution of the bundles in the sub-dermal zone, ×55. Fig. 9. Form and distribution of the bundles in the central zone, ×55. Fig. 10. A fibrovascular bundle from the central zone enlarged to show the tabular parenchyma, ×110. Fig. 11. An abnormal bundle from the central zone, ×110. Fig. 12. Cells of the ground parenchyma in the central zone, ×110.

parenchyma is abundantly represented. The distribution of the bundles is irregular in that some of them are normally oriented, others face the peripheral part of the stem, while a third type is obliquely placed

(Text-Fig. 9; Pl. XII, Fig. 7). The bundles are elliptic or broadly oval and the *f*/*v* ratio is usually 1½/1. The median sinus usually makes the sclerenchyma cordate, *albeit* reniform sclerenchyma also occurs at places. The auricular sinus is meagrely developed and the auricular lobes pass insensibly into the lateral sides of the xylem. There are no stegmata. The xylem portion consists of 2–3 large, oval to rounded metaxylem elements with a few protoxylem vessels (2–4) placed internal to them. The phloem is not preserved in any of the bundles. Tabular parenchyma is a common feature and two-layered (Text-Fig. 10). Whenever two fibrovascular bundles lie contiguous to each other they, more often than not, tend to fuse with each other along their sclerenchyma sheaths (dorsal sides) resulting in a bizarre bundle with two xylem patches on either side (dorsal and ventral) and a common sclerenchyma sheath in between (Text-Fig. 11).

Leaf trace bundles (Kreuzungsbundel of Stenzel) are present throughout the stem but are best seen in the subdermal and central zones. These are by far the largest bundles in the stem and easily recognised by their very well-developed vascular part which protrudes in the form of a tongue far out of the median sinus. The protoxylem of these traces is invariably capped by a ventral sclerenchymatous arc. The relative distribution of the leaf traces is not similar throughout the stem; they are more commonly met with in the subdermal zone compared to the other regions. Leaf trace bundles in the central zone although not as well preserved as those in the subdermal zone are distinguishable from the latter in one important feature and that is, the presence of 1–3 layered radiating parenchyma in the immediate vicinity of these traces. In almost all the sections examined the leaf traces in the central zone are surrounded by a more or less distinct radiating parenchyma, which, consequently may be considered as a constant feature (Text-Fig. 5). The significance of the radiating parenchyma around the leaf traces of the central zone alone, is not known.

The pitting of the metaxylem vessels is of the multiseriate scalariform type (Pl. II, Fig. 9). The perforated end walls of the vessels are obliquely placed and show a series of (8–18) widely spaced parallel bars of thickening, allowing uninterrupted vertical communication; these scalariform bars are often branched once or twice (Text-Fig. 6).

The ground tissue is compact throughout the stem, consisting of more or less thick-walled parenchymatous cells (Text-Fig. 12; Pl. XII, Fig. 8). The cells are angular and none of them show any lobes or processes. Because of considerable space between the fibrovascular bundles in the central zone the parenchyma cells of the ground tissue tend to be broader and less angular in this part of the stem. In longitudinal sections these cells are seen to be placed contiguously in a series of vertical rows (Text-Fig. 4; Pl. XII, Fig. 9) as in living palm stems; this alignment suggests that the rows have been formed by horizontal divisions of the cells followed by vertical stretching during the elongation of the stem. The parenchyma cells in general are empty.

Discussion

So far there is no available system for the natural classification of the petrified palm stems, which usually are grouped under the avowedly heterogeneous form genus *Palmoxylon* Schenk. Based on an extensive study of the modern palms Kaul in 1935 had reported that palm stems could be identified by the structural details of their ground tissue pattern. However, Kaul's treatise on the anatomy of palms is yet to be published in full. As things stand, the only course open is to classify the genus artificially. The criteria which have been found most reliable in the determination and classification of palm stems are the form, distribution and orientation of the fibrovascular bundles, and the parenchyma pattern of the ground tissue.

In 1943 Prof. Sahni prepared a scheme based jointly on the classifications of Van Mohl (1849) and Stenzel (1904). The author proposes to follow this scheme which under the existing circumstances seems to be very convenient and practicable. According to this, *Palmoxylon puratanum* falls under the group Corypha-like palms and the subgroup *cordata*. It should, however, be mentioned that the author recognises the artificial nature of the genus *Palmoxylon* which has been employed here in a tentative manner pending a natural classification of fossil palms based on a comprehensive study of the stem anatomy of the modern palms.

Comparisons with the Indian Palmoxyla.—Palmoxylon sclerodermum (Sahni, 1943; Shukla, 1946) described from the Deccan Intertrappean series resembles our fossil in (1) the general appearance and orientation of the fibrovascular bundles, (2) the sculpturing of the xylem elements and (3) the general form of the leaf trace bundles. The two species, however, are quite different from each other in a number of other important features. Purely fibrous bundles in addition to the normal bundles are commonly present in the dermal, subdermal and central zones of *P. sclerodermum*, whereas such bundles are conspicuous by their absence in the corresponding zones of our species. The fibrovascular bundles are more crowded and bigger, and their *f*/*v* ratio is higher in *P. sclerodermum* than in the present species. In the Intertrappean species stegmata are commonly present around the normal bundles while no such structures are seen in the South Indian species. Besides, in *P. puratanum* distinct radiating parenchyma is seen around the leaf trace bundles of the central zone while such a feature is absent in the Intertrappean fossil. Further, the general pattern of the ground tissue is also different in both the species; in *P. sclerodermum* the ground parenchyma cells are more rounded, isodiametric and lobed and the ground tissue becomes loose (soft) and lacunar as we proceed from the periphery toward the interior, while in our fossil the cells are more consistently angular and without any lobes or processes and the ground tissue is uniformly compact throughout.

With *P.* (*cocos*) *sundaram* (Sahni, 1946) also our fossil shows some resemblances in (1) the general appearance, orientation and distribution of the fibrovascular bundles, (2) the *f*/*v* ratio, (3) the sculpturing of

the elements, (4) the structure and distribution of the leaf traces, and (5) in the presence of numerous purely fibrous bundles in the cortical zone. But *P. (cocos) sundaram* differs at the same time, from our fossil in possessing characteristic diminutive bundles in all the three zones, stegmata around the normal bundles and lastly in its ground tissue which becomes loose and distinctly soft and lacunar from without inwards. Moreover, there is no radiating parenchyma in the central zone of the Intertrappean fossil.

Palmoxylon surangei (Lakhanpal, 1955), described recently from the Deccan Intertrappean series of India, is similar to our fossil in the general nature and distribution of the fibrovascular bundles, in the cordate median sinus, in the general nature of the leaf traces, and lastly in the uniformly compact nature of the ground parenchyma. In a number of other characters the two species, however, are quite distinct from each other. Thus, the cortex in *P. surangei* contains numerous fibrovascular bundles and only a few purely fibrous bundles while in our specimen the opposite is the case; in *P. surangei* the fibrovascular bundles of all the three zones do not show any appreciable difference in size within themselves, while in our fossil the size of the bundles gradually increases from without inwards. Purely fibrous bundles and stegmata are present in the dermal, subdermal and central regions of the Intertrappean specimen while they are absent in our specimen; the perforations of the xylem vessels are reticulate in the former and obliquely scalariform in the latter and last but not the least in *P. surangei* the sclerenchyma of some outer rows of the dermal bundles is externally surrounded by radially elongated parenchyma cells, a feature which is not seen in our species.

Mention may be made of *P. arcotense* (Ramanujam, 1953 *a*) and *P. pondicherriense* (Sahni, 1931) described from the same district as that of the present fossil. *P. arcotense* is comparable with the present species in possessing a cordate median sinus, but differs greatly from the latter in having extremely lacunar ground tissue. *P. pondicherriense* bears no comparison whatsoever with the present species; its chief characters are (1) decrease in size of the bundles from without inwards and (2) varying forms of the sclerenchyma of the normal bundles.

Comparison with the foreign species.—Of the foreign species *Palmoxylon confertum* (Stenzel, 1904), *P. densum* Schenk and *P. speciosum* Schenk, redescribed by Stenzel (1904) can to some extent be compared with the South Indian species.

P. confertum agrees with our fossil in the general nature and distribution of the brovascular bundles and in lacking stegmata but the former differs in consistantly possessing a shallow (*complanata-type*) median sinus.

P. densum is known only by the external parts of the stem. It resembles our fossil in the structural details of the fibrovascular bundles, the general form of the leaf traces and in the compact nature of the ground tissue, but since the central zone of the stem is not available

in the former it is not known whether the ground tissue is uniformly compact throughout. Besides, there are a number of other important differences between *P. densum* and the South Indian species. The fibrovascular bundles become somewhat smaller as we proceed inwards in the former, while opposite is the case in our fossil. The median sinus is nearly always reniform in *P. densum* and cordate in *P. compactum*. Further, purely fibrous bundles are present in all the zones of *P. densum* while they are completely absent in the dermal, subdermal and central zones of our species.

In the general nature and orientation of the vascular bundles and leaf traces our fossil also resembles *P. speciosum*. However, in the latter the ground parenchyma cells are elongated and the fibrous part of the vascular bundles is mostly sagittate. Besides, fibrous bundles and stegmata are commonly present in *P. speciosum*.

The fossil described here is named *Palmoxylon puratanum*. The specific name *puratanum* is from the Sanskrit word *puratanum* (पुरातनम्) meaning ancient.

Diagnosis

Genus—*Palmoxylon* Schenk

Subgroup—*Cordata*

Palmoxylon puratanum sp. nov.

Stem encircled by a leaf sheath region consisting of closely packed parenchyma cells and purely fibrous bundles; cortex meagrely developed, composed of numerous purely fibrous bundles with 15–40 fibres and abundant solid dark deposits; fibrovascular bundles sporadic. Dermal and subdermal zones fairly well developed, central zone seems to be quite broad.

Fibrovascular bundles in the dermal zone normally oriented, closely packed leaving little or no ground tissue in between; generally elliptical, $0{\cdot}8 \times 0{\cdot}5$ mm. in size and 80–100 per cm.^{2}; median sinus rounded cordate, f/v ratio 4/1; a single large xylem vessel excluded from the sinus in each bundle; ground tissue meagre, compact; leaf traces common; purely fibrous bundles and stegmata absent.

Fibrovascular bundles in the subdermal zone 65–75 per cm.^{2}; normally oriented, $0{\cdot}95 \times 1{\cdot}2$ mm. in size, and elliptic or broadly oval; median sinus cordate; f/v ratio 3/2 to $1\frac{1}{2}/1$; auricular sinuses insignificant, auricular-lobes pass insensibly into the sides of the xylem; tabular parenchyma common, two-layered; xylem consisting of two metaxylem vessels placed side by side, and 1–3 protoxylem elements; ground tissue fairly well developed, cells compactly packed; leaf traces very common; purely fibrous bundles and stegmata absent.

Fibrovascular bundles in the central zone 20–25 per cm.^{2}; $1{\cdot}1 \times 1{\cdot}5$ mm. in size, irregularly oriented, elliptic or broadly oval; median sinus cordate, at times becoming reniform; f/v ratio $1\frac{1}{2}/1$;

auricular sinuses poorely developed, auricular lobes pass insensibly into the sides of the xylem; adjacent bundles often fuse by their dorsal facets to form bizarre bundles with a central sclerenchymatous sheath and dorso-ventral xylem portions; tabular parenchyma common, two-layered; xylem consisting of a pair of large vessels placed side by side and 2–4 protoxylem elements; ground parenchyma profusely developed, cells more or less angular, compactly placed and possess no lobes or processes. Leaf traces seen quite often, commonly surrounded by a distinct radiating parenchyma of 1–3 layers.

Thickening of the metaxylem vessels multiseriately scalariform; end walls oblique with 8–18 widely spaced parallel bars.

Summary

A new species of petrified palms, *Palmoxylon puratanum* has been described from the Tertiary rocks of South Arcot District, Madras. The specimen was collected from near Mortandra, 5 miles N.-W. of Pondicherry. It belongs to the subgroup *cordata* of the petrified palm stems.

Acknowledgements

The author feels it a pleasure to express his gratitude to Prof. J. Venkateswarlu for his keen interest and encouragement during the progress of this work. To the Ministry of Education, Government of India, he is thanktul for the award of a National Research Fellowship.

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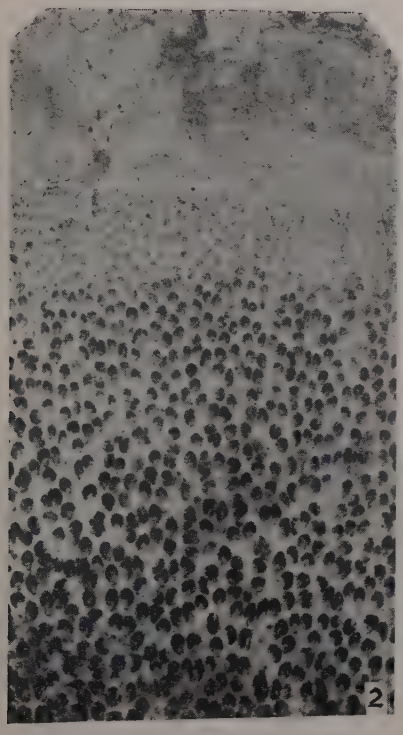

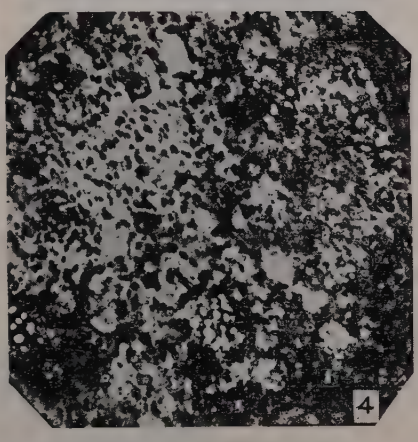

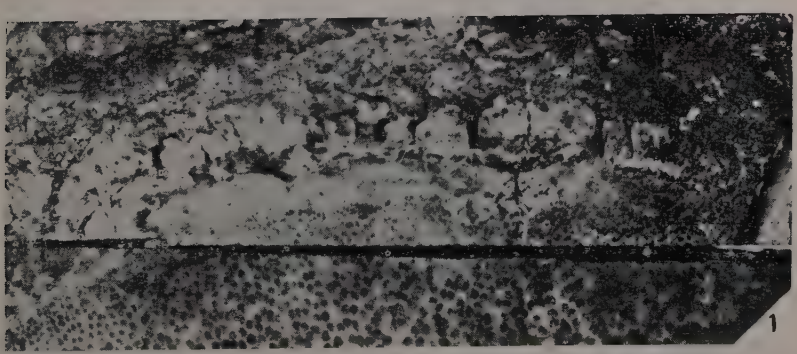

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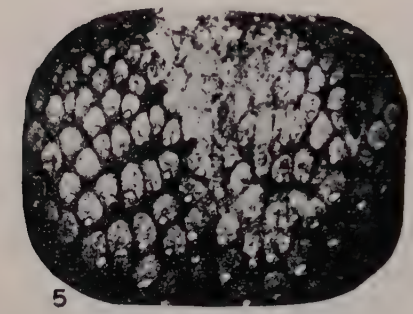
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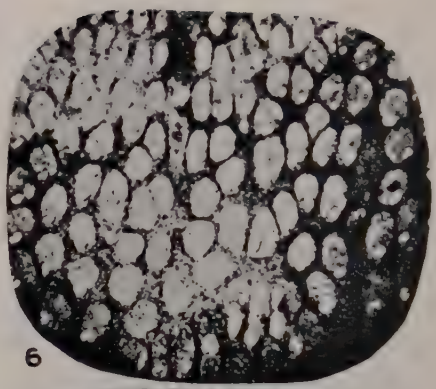
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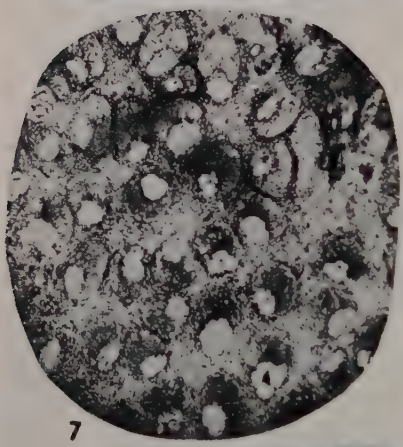
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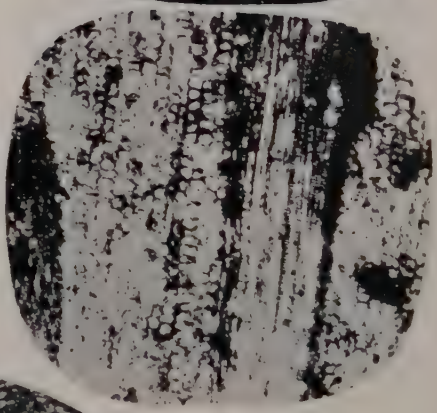
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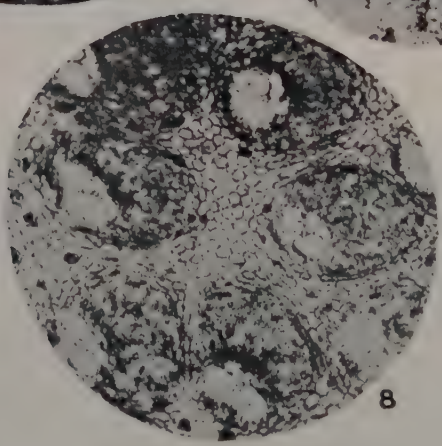
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EXPLANATION OF PLATES

PLATE XI. *Palmoxylon puratanum* sp. nov.

FIG. 1. Part of cross-section through the external layers. Note the leaf sheath region and the cortical portion, ×*c.* 2.

FIG. 2. Part of cross-section through the dermal and subdermal zones, ×*c.* 3·2.

FIG. 3. Part of cross-section through the leaf sheath region, enlarged, ×40.

FIG. 4. Part of cross-section through the cortical portion showing the purely fibrous bundles and the solid dark deposits, ×40.

PLATE XII. *Palmoxylon puratanum* sp. nov.

FIG. 5. Part of cross-section through the dermal zone, ×40.

FIG. 6. Part of cross-section through the subdermal zone, ×40.

FIG. 7. Part of cross-section through the central zone, ×40.

FIG. 8. Fibrovascular bundles and the ground tissue from the central zone, slightly enlarged, ×40.

FIG. 9. Part of longitudinal section through the central zone. Note the multiseriate scalariform pitting on the vessels, ×40.

NOTES ON INDIAN RED ALGÆ—I

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(With 21 Text-Figures)

(Received for publication on December 16, 1957)

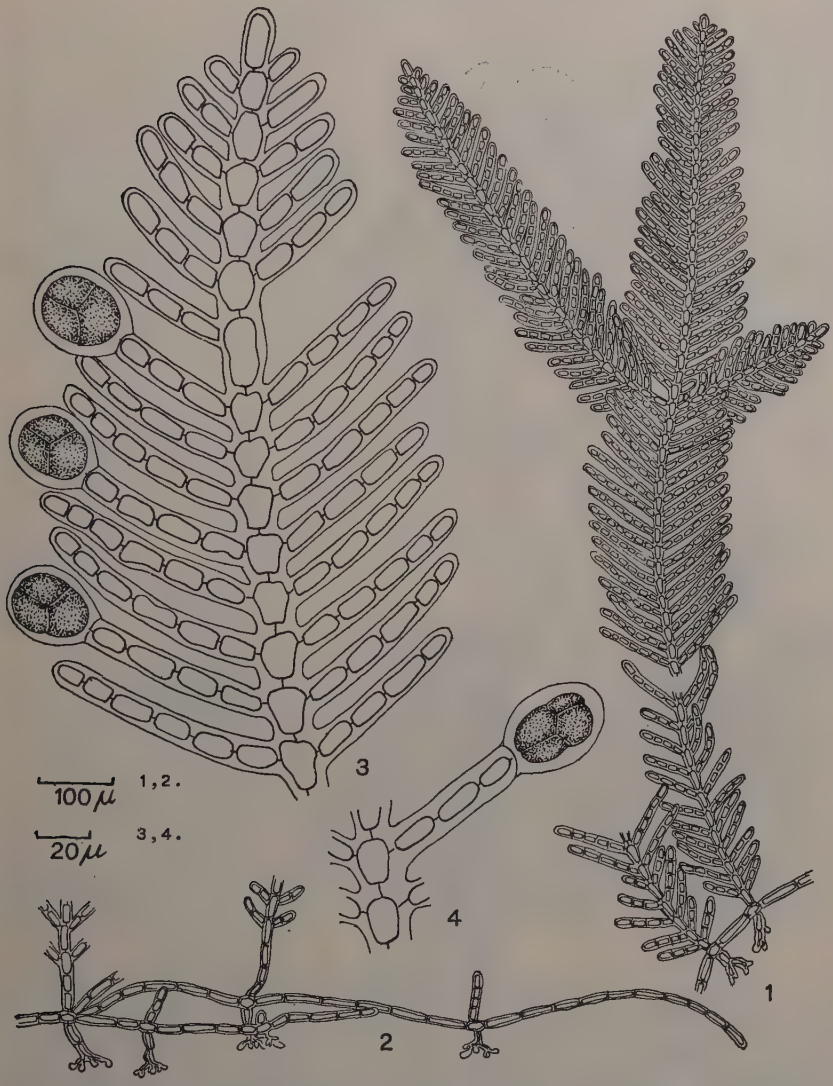
During a special study of Indian red algæ, the writer came across two interesting epiphytic red algæ belonging to the family Ceramiaceæ. These are described in the present paper.

Gymnothamnion elegans (Schousboe) J. Agardh

This alga was collected growing on *Corynomorpha prismatica* (Ag.) J. Ag. from Cape Comorin, South India. It forms small bright red tufts 1–1½ cm. high on the basal portions of the host. The prostrate creeping portion consists of branched filaments fixed to the host by means of multicellular rhizoids at intervals (Text-Fig. 2). The cells of the creeping filaments are cylindrical, 10–12 $\mu \times$ 30–45 μ and thick walled. The cells giving rise to rhizoids are much shorter than the others and these also give rise to erect branches on the upper side (Text-Fig. 1). The erect branches are 10–15 mm. in height, plumose, usually simple, but occasionally pinnately branched; cells of the erect branches are up to 25 μ long and 10–15 μ wide. Generally they are slightly broader at the top (Text-Fig. 3). Each cell bears at the top a pair of opposite branchlets (pinnules) six to eight cells long, the cells measuring 10–12 $\mu \times$ 10–18 μ. The branchlets are distichously arranged and except in the youngest parts, almost of uniform length so that the erect branches are characteristically plumose and oblong or linear lanceolate in outline (Text-Fig. 1). Production of the branchlets starts right from the base (Text-Fig. 1); it is only in the older stages that the lower parts of the erect branches become bare, evidently due to the dropping off of older branchlets. Both the prostrate and erect filaments are totally ecorticate.

The tetrasporangia are borne terminally on the branchlets. They are ellipsoid to ovate, 25–30 μ wide and 30–40 μ long. The tetraspores are usually pyramidally arranged (Text-Fig. 3), but cruciate arrangement is also frequently met with (Text-Fig. 4) (see also Bornet and Thuret, 1876, Plate X, Fig. 2).

The alga is diœcious. Spermatangia are borne in clusters on short multicellular accessory branches at the tips of the branchlets (Text-Figs. 7, 8). Each cell of these lateral branches functions as a spermatangial mother cell and bears two to three spermatangia at the top, (Text-Fig. 11) (see also Bornet and Thuret, 1876, Plate X, Fig. 3).



TEXT-FIGS. 1–4. *Gymnothamnion elegans*. Fig. 1. Part of plant showing general habit and branching. Fig. 2. Part of creeping filament to show branching and rhizoids. Figs. 3–4. Portions of erect branches to show tetrasporangia.

Development of the procarp up to fertilization

The procarps are borne on the branchlets near the tips, usually on the subterminal cell. The sequence of development is as follows: The subterminal cell first cuts off a pericentral cell on the abaxial side (Text-Fig. 5), and a little later, one more pericentral cell is cut off laterally (Text-Fig. 6, *pc*). The abaxial pericentral cell divides further

TEXT-FIGS. 5–12. *Gymnothamnion elegans*. Fig. 5. First stage in the formation of the procarp. Fig. 6. A later stage showing the carpogonial branch initiated and the lateral pericentral cell formed. Figs. 7–8. Tips of branchlets from a male plant showing early stages in the formation of the spermatangia. Fig. 9. Young procarp showing the four-celled carpogonial branch with the trichogyne just developing and the lateral sterile branch with its terminal hair. Fig. 10. Early stage in gonimoblast formation. Fig. 11. Tip of branchlet from male plant showing fully formed spermatangia. Fig. 12. Early post-fertilization stage showing division of the carpogonium into three cells and the auxiliary cell cut off from the supporting cell. (*aux*, auxiliary cell; *cbr*, carpogonial branch; *cc*, connecting cell; *cpg*., carpogonium; *gon*, gonimolobes; *pc*, lateral pericentral cell; *sc*, supporting cell; *st*, lateral sterile branch.)

to produce a four-celled carpogonial branch and a two to three-celled lateral sterile branch (Text-Fig. 9, *St*). This lateral sterile branch is initiated when the carpogonial branch has started development and is two to three cells long. The terminal cell of the carpogonial branch develops into the carpogonium with a long trichogyne while that of the lateral sterile branch develops into a long unicellular hair (Text-Figs. 9, 12). The lateral pericentral cell of the fertile segment usually remains undivided during later stages of development (Text-Figs. 10, *pc*; 12, 13, 14), but it occasionally grows into a two to three-celled branch sometimes terminating in a hair (Text-Fig. 9, *pc*). It has also been observed that the lateral sterile branch is always formed on the side away from the lateral pericentral cell (Text-Figs. 9, 12). Thus, at the time of fertilization, the supporting cell (Text-Fig. 9, *Sc*) carries: (1) a four-celled carpogonial branch on one side and (2) a two to three-celled lateral sterile branch on the other.

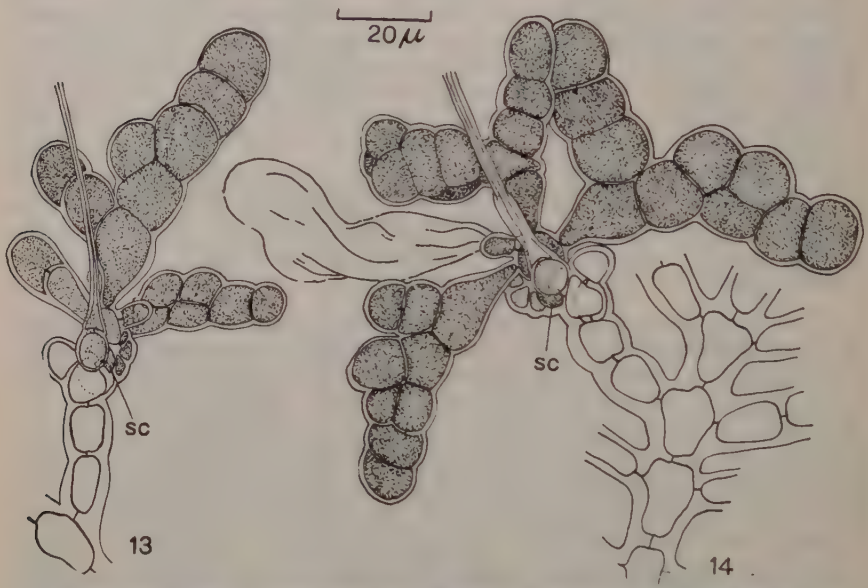
The sequence of development described agrees with that described for the Mediterranean form of this alga (as *Callithamnion elegans* Schousboe) by Bornet and Thuret (1876) and for *Ptilota* (Kylin, 1923) and *Plumaria* (Suneson, 1938; Drew, 1939). In all these cases the first formed abaxial pericentral cell produces a four-celled carpogonial branch and a two-celled lateral sterile branch. However, in *Ptilota* and *Plumaria* the fertile segment has two lateral pericentral cells, one on either side of the supporting cell, whereas in *Gymnothamnion* there is only one lateral pericentral cell (*cf.* Bornet and Thuret, 1876, p. 33).

Again, in *Ptilota* (Kylin, 1923) the terminal cell of the fertile branchlet, the two lateral pericentral cells of the procarpic segment and the lateral sterile cell of the procarp all develop into branches ending in terminal hairs so that the fertile branchlet is crowned by a group of four hairs. In *Plumaria* on the other hand (Suneson, 1938; Drew, 1939) only the lateral sterile branch of the procarp always bears a terminal hair; hair formation by one or more of the other branches is generally suppressed. It is, however, interesting to observe that Bornet and Thuret (1876, Plate X, Fig. 4), show a fertile branchlet of *Gymnothamnion elegans* from the Mediterranean crowned with five hairs.

Development of the procarp after fertilization

After fertilization, the trichogyne is first cut off. The fertilized carpogonium then divides to form three cells, the lowest of which functions as a connecting cell (sporogenous cell) and fuses with the auxiliary cell (Text-Fig. 12, *cc*). As in all Ceramiales, the auxiliary cell is cut off from the supporting cell only after fertilization and lies in close proximity to the carpogonium (Text-Fig. 12, *aux*). After fusion of the carpogonium and the auxiliary cell is effected, the trichogyne seems to wither away. The carpogonium and the carpogonial branch cells also start degenerating. The auxiliary cell now divides into an upper larger and lower smaller cell. The former is the gonimoblast initial while the latter forms the so called 'foot cell.' The gonimoblast initial, in its turn, gives rise to three to five gonimolobes

(Text-Fig. 10, *gon*). Each gonimolobe consists of a compact, branched stout gonimoblast cluster, the lowermost cell of which forms a stalk while all other cells produce carpospores (Text-Figs. 13, 14). The



TEXT-FIGS 13–14. *Gymnothamnion elegans*. Figs. 13–14. Young and old cystocarps showing structure and the persistent lateral sterile branch with its terminal hair. (*sc*, supporting cell.)

carpospores are quite large, bright red, and measure 15–20 μ in diameter. After the liberation of carpospores, the empty outer sheath persists as a transparent sac for sometime (Text-Fig. 14). Vestiges of the carpogonial branch can be made out even in the ripe cystocarps. The lateral sterile branch with its terminal hair always persists and is prominently seen in the fructifications (Text-Figs. 10, 13, 14).

Bornet and Thuret (1876) have given an account of the asexual and sexual reproduction of this alga. The present account agrees in general with their observations. In this paper the writer has given details of early post-fertilization development also. The details of early post-fertilization development are in agreement with what has been described for the related genera *Ptilota* (Kylin, 1923) and *Plumaria* (Suneson, 1938; Drew, 1939). In these two genera, the carpogonium after fertilization divides into two cells, the lower of which functions as the connecting cell (sporogenous cell) and fuses with the auxiliary cell. The present observations indicate that the Indian *Gymnothamnion* differs from these and shows similarity to genera like *Antithamnion* in the division of the fertilized carpogonium into three cells, the lowermost of which establishes connection with the auxiliary cell.

Callithamnion elegans Schousboe ex C. Agardh (1828, p. 162) was transferred to *Plumaria* Schmitz (*non Plumaria* Stackhouse) by Schmitz in 1889 as *P. schousboei* (Bornet) Schmitz. J. Agardh (1892), however, segregated it as a new genus, *Gymnothamnion* [type species, *G. elegans* (Schousboe) J. Ag.]. *Gymnothamnion* is distinguished from *Plumaria* Schmitz by its small size, absence of cortication and simple unbranched nature of the branchlets. The present study indicates that the formation of only one lateral pericentral cell in the fertile segment and the division of the fertilized carpogonium into three parts may serve as additional distinguishing features.

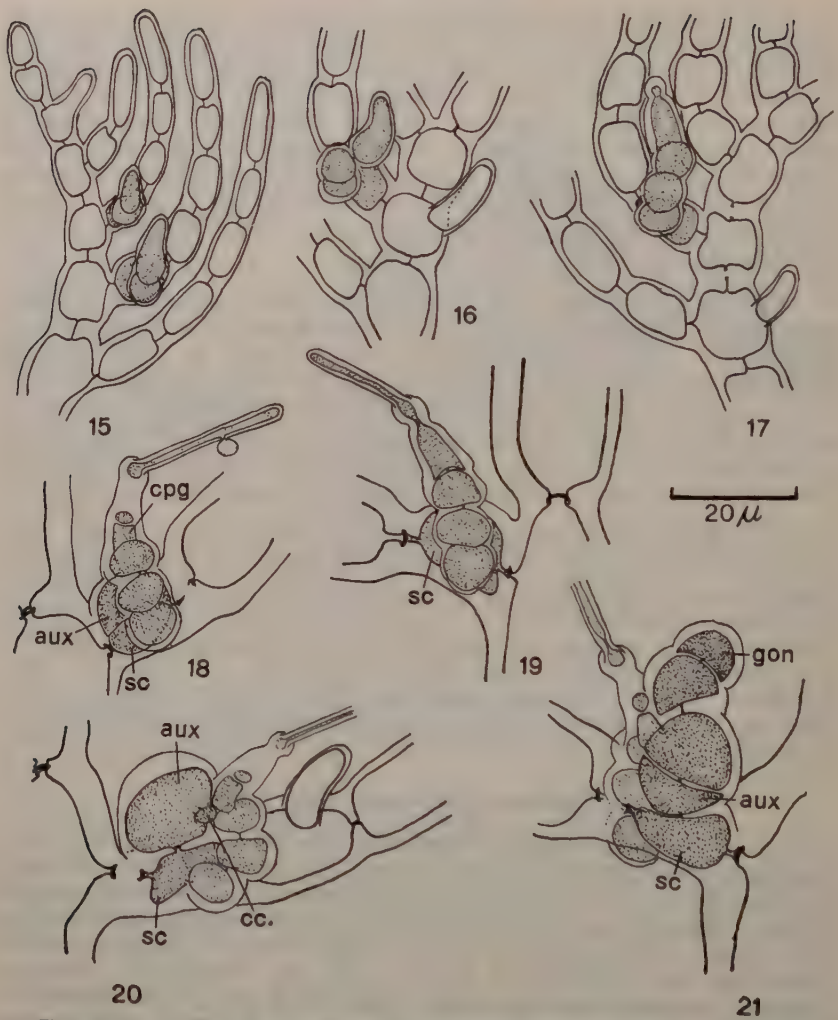
Collins and Hervey (1917) added two more species to *Gymnothamnion*, *G. sericeum* (Harvey) Collins *et* Hervey and *G. bipinnatum* Collins *et* Hervey. Feldmann-Mazoyer (1940, p. 353) included *G. bipinnatum* as well as *Plumaria ramosa* Yamada and Tanaka (1934) in *G. elegans*. She, however, was not certain whether *G. sericeum* and *G. elegans* could be kept in the same genus. Later, she (1950, p. 310) kept only *G. elegans* in the genus, transferring *G. sericeum* to *Plumaria* Schmitz as a synonym of *Plumaria elegans* (Bonnem.) Schmitz.

The genus *Gymnothamnion* is, thus, monotypic (see Kylin, 1956, p. 389; see also Silva, 1952, p. 288). *G. elegans* is known from the Mediterranean and adjoining parts of the Atlantic Ocean, Bermuda, the Canary Islands, Formosa (Japan), the Pacific coast of Mexico, Clarion Island in the Revillagagido Archipelago, Isabella Island on the Equador coast and New Zealand (Setchell and Gardner, 1930; Schiffner, 1931; Feldmann-Mazoyer, 1940, 1950; Taylor, 1945; Dawson, 1953; Kylin, 1956). It is recorded here for the first time from India.

Antithamnion floccosum (Müll.) Kleen.

A single small female plant of this alga was found growing on a specimen of *Halymenia floresia* (Clem.) Ag. collected from Tuticorin by Prof. M. O. P. Iyengar who kindly passed on the material to the writer. The plant was about 6 cm. high and showed the lax branching, with basal portions almost bare, characteristic of the species. The branching was subalternate pinnate and the branchlets (pinnules) incurved, arising from the upper portions of the articulations. The branchlets were opposite and distichous, simple, often with unequal development, the branchlet on the inner side reduced to one or two cells. The tips of the branches and branchlets were somewhat pointed in the older portions and rounded in the younger portions. Gland cells were not seen.

The material showed stages in procarp development and also early post-fertilization stages, though lacking ripe cystocarps. The procarps occur near the growing tips, the basal cell of a normal fully developed branchlet serving as the supporting cell of the carpogonial branch (Text-Figs. 15, 17). The carpogonial branch is four-celled; the terminal cell is the carpogonium and has a well-developed trichogyne (Text-Fig. 19).



TEXT-FIGS. 15–21. *Antithamnion floccosum.* Figs. 15–17. Stages in the development of the procarp. Fig. 18. Procarp after fertilization showing division of the carpogonium into two cells and the cutting off of the auxiliary cell from the supporting cell. Fig. 19. Procarp prior to fertilization. Fig. 20. Procarp after fertilization showing the connecting cell. Fig. 21. Still later stage, showing initiation of gonimoblast. (*aux*, auxiliary cell; *cc*, connecting cell; *cpg*, carpogonium; *gon*, gonimolobe; *sc*, supporting cell.)

After fertilization, the trichogyne is first cut off; the carpogonium then divides to form an upper smaller and a lower larger cell (Text-Fig. 18, *cpg*). At about this stage, the supporting cell also cuts off the auxiliary cell on the upper side (Text-Fig. 18, *aux*). After the formation of the auxiliary cell, the lower derivative of the fertilized carpogonium cuts off a small cell on the under side (Text-Fig. 20, *cc.*)

which functions as a connecting cell between it and the auxiliary cell. After this connection is established, the carpogonial branch starts degenerating. The auxiliary cell next divides into an upper large gonimoblast initial and a lower small foot cell. The gonimoblast initial gives rise to the gonimolobes (Text-Fig. 21, *gon*).

The details of development recorded here agree with what has already been reported for other species of *Antithamnion* by various workers (Phillips, 1897; Daines, 1913; Kylin, 1923, 1925; Rosenvinge, 1924; Capt, 1930; Westbrook, 1934; Levring, 1941; Segawa, 1949; Chadefaud, 1954).

Species of *Antithamnion* are clearly divisible into two groups, (1) in which the procarp is borne on the basal cell of a fully developed branchlet [*A. plumula* (Ellis) Thuret, *A. occidentale* Kylin, *A. tenuissimum* (Hauck) Schiffner, *A. floccosum* (Müll.) Kleen, *A. subulatum* (Harv.) J. Ag., and *A. minutissimum* Levring] and (2) in which the fertile branchlet is reduced and is one to three cells long [*A. pacificum* (Harv.) Kylin and *A. spirographidis* Schiffner] (see Feldmann-Mazoyer, 1940; Kylin, 1956).

Only two other species of *Antithamnion* appear to have been previously reported from this region, *viz.*, *A. plumula* (Murray, 1881, p. 5, as *Callithamnion plumula* Lyngb.) and *A. elegans* Berthold (Anand, 1943, p. 22, Figs. 14–15), both records being from Karachi.

Summary

Gymnothamnion elegans (Schousboe) J. Ag. (Ceramiaceæ, Ptiloteæ) and *Antithamnion floccosum* (Müll.) Kleen (Ceramiaceæ, Crouanieæ) are reported for the first time from India.

The structure and reproduction of *G. elegans* is described in detail, especially the development of the procarp before and after fertilization. Points of interest and the taxonomy of the genus are briefly discussed.

Development of the procarp and early post-fertilization stages in *A. floccosum* are also described.

The writer is indebted to Profs. M. O. P. Iyengar and T. S. Sadasivan for encouragement and to Dr. T. V. Desikachary for critically going through the paper and for helpful suggestions.

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FLORAL ANATOMY AND EMBRYOLOGY OF *CIPADESSA BACCIFERA* MIQ.

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(Received for publication on September 16, 1957)

Introduction

The family Meliaceæ comprises 50 genera and 800 species (Lawrence, 1951). It is included in the order Geraniales by Bentham and Hooker (1862–1893) and Engler and Diels (1936). Rendle (1938) includes the family in his Rutales along with Simaroubaceæ, Burseraceæ and Rutaceæ. It is the only family in the Meliales of Hutchinson (1926) who places the order after the Rutales.

Our knowledge of floral anatomy in the family is meagre. Saunders (1937) made a study of *Melia azaderach*. The flowers are hypogynous, isomerous with the floral parts arranged in six whorls. Sepals have commissural marginal veins. Traces for the stamens arise independently from the main stele. Dorsal carpellary traces are lacking. Ventrals continue into the style. Recently Nair (1956 *a*) studied the placentation in *Melia azadirachta* (*Azadirachta indica*) and concluded that the placentation is parietal on the basis of vascular anatomy.

The embryological work done in the family till 1930 was summarised by Schnarf (1931). Since then the important work in the family is by Wiger (1935) who studied 40 species, distributed in 13 genera. More recently Garudamma (1956 and 1957) has studied the embryology of *Melia azadirachta* and Nair (1956 *b*) studied the development of endosperm in three species. The embryological features may be summarised as follows:

The anther structure shows an epidermis and 4–5 wall layers. The hypodermal wall layer develops into the fibrous endothecium in the mature anther. The tapetum is of the secretory type. The tapetal cells ultimately become 2–4 nucleate. Divisions of the pollen mother cells is simultaneous. Pollen tetrads show tetrahedral or decussate arrangement. The pollen grains are 4-porate and are 2-celled at the shedding stage.

The ovules are crassinucellate, bitegmic and anatropous.

The primary archesporium in the ovule is single-celled and hypodermal. Parietal layers of varying number are present. The development of the embryo-sac follows the normal type.

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Fertilisation is porogamous.

Endosperm is free nuclear. X-bodies also occur.

The embryo development follows the third megarchetype, in the first period.

Material and Method

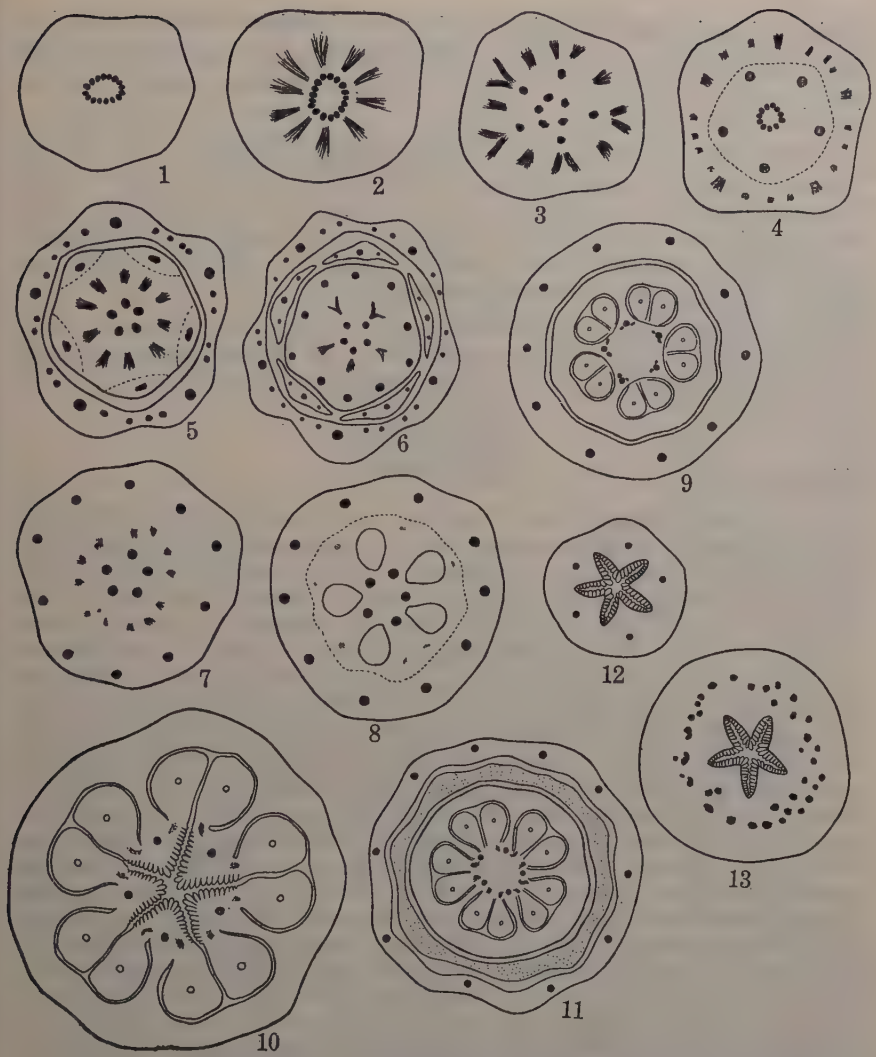
The flowers of *Cipadessa baccifera* were fixed in F.A.A. Usual methods of dehydration, infiltration and embedding were followed. Sections were cut at a thickness of 6–12 μ and were stained in crystal violet using erythrosine as counter-stain.

Observations

Floral Anatomy

The flower of *Cipadessa* is pentamerous and bisexual. The perianth is represented by two whorls of which the calyx is gamosepalous. The stamens are ten, united into a tube and the anthers separate from it at the top. The ovary is five carpellary, syncarpous, five locular at the base, but at a higher level the septa do not meet in the centre. The margins of the septa are lined by glandular hairs (Fig. 10) which are multicellular (Fig. 24). In each loculus there are two ovules (Figs. 9, 10 and 11). A disc is present between the androecium and gynoecium, and it is carried with the staminal tube for some distance.

The pedicel in its structure shows a ring of closely placed vascular bundles (Fig. 1). Ten traces arise from the main stele and of these ten traces five represent the sepal midribs and the remaining five represent the conjoint traces of sepal laterals and petal midribs (Fig. 2). These conjoint traces divide forming an inner ring of petal midrib bundles (Fig. 3) and then outer five diverge out along with the sepal midribs to enter the base of the gamosepalous calyx (Figs. 3 and 4). These later divide to form smaller bundles (Figs. 5 and 6). The petal midrib bundles are seen at the periphery of the thalamus at the level of separation of the calyx from the floral axis (Fig. 4). At a higher level the petals also separate from the floral axis (Fig. 5) and the bundles supplying them also divide and form smaller bundles after entering them (Fig. 6). At about the level where the petals separate from the floral axis, ten traces for the ten stamens arise, all at the same level from the main stele (Fig. 5). These proceeding peripherally enter the base of the staminal tube (Figs. 7 and 8). At about the level at which the bases of the loculi appear, the staminal tube which carries with it the disc, separates from the floral axis (Figs. 8 and 9). The disc, however, separates from the staminal tube at a higher level (Fig. 11). After the traces for the stamens are given out the main stele forms five bundles from which arise five dorsal carpellary traces (Fig. 6). These divide to form smaller bundles which ramify near about the central stele (Fig. 7). These, however, fade out at a higher level (Fig. 8). The remaining part of the stele forms the ventral supply and these bundles lie on the septal radii (Figs. 8, 9, 10 and 11). Branches from these



FIGS. 1–13. *Cipadessa baccifera* Miq. Serial transverse sections of the flower. Fig. 1. Stele of pedicel, ×28. Fig. 2. Origin of sepal midribs and conjoint traces of sepal laterals and petal midribs, ×14. Fig. 3. Demarcation of petal midrib bundles by tangential splitting of the conjoint traces of sepal laterals and petal midribs, ×14. Fig. 4. Separation of gamosepalous calyx from floral axis. Petal midrib bundles are seen at the periphery of thalamus, ×14. Fig. 5. Separation of petals and origin of staminal traces. Calyx is also represented, ×14. Fig. 6. Origin of dorsal carpellar traces. Staminal traces are seen at the periphery of thalamus. Calyx and corolla are also shown, ×14. Fig. 7. Branching of dorsal carpellary traces. Staminal traces are seen at the periphery, perianth not represented, ×28. Fig. 8. Separation of staminal tube, bases of loculi appearing. Fading branches of dorsal carpellary traces are seen in the ovary wall, ×28. Fig. 9. Ovary showing the 5 loculi with two ovules in each and branches from the ventral bundles which supply the ovules. Staminal tube separated, ×28. Fig. 10. Same as above enlarged

to show glandular nature of margins of the septa which have not fused. Staminal tube not represented, ×43. Fig. 11. Separation of disc from the staminal tube disc dotted, ×28. Fig. 12. Stylar canal lined by glandular cells. Note the five ventral bundles, ×56. Fig. 13. Top of style showing small strands formed by branching of ventrals, ×56.

supply the ovules (Figs. 9, 10 and 11). After supplying the ovules the ventrals give out small branches which enter the wall of the ovary. The ventrals further continue to the top of the style (Fig. 14) where they divide to form a large number of strands (Figs. 13 and 14). The stigma bears a large number of hairs (Fig. 14 and 15). The style shows a central cavity lined by glandular cells (Fig. 12).

The placentation in the family has been described as axile. But in the light of Puri's (1952) revised concept of placentation, *Cipadessa* has parietal placentation as in *Melia azadirachta* (Nair, 1956).

Embryology

Microsporogenesis and Male Gametophyte

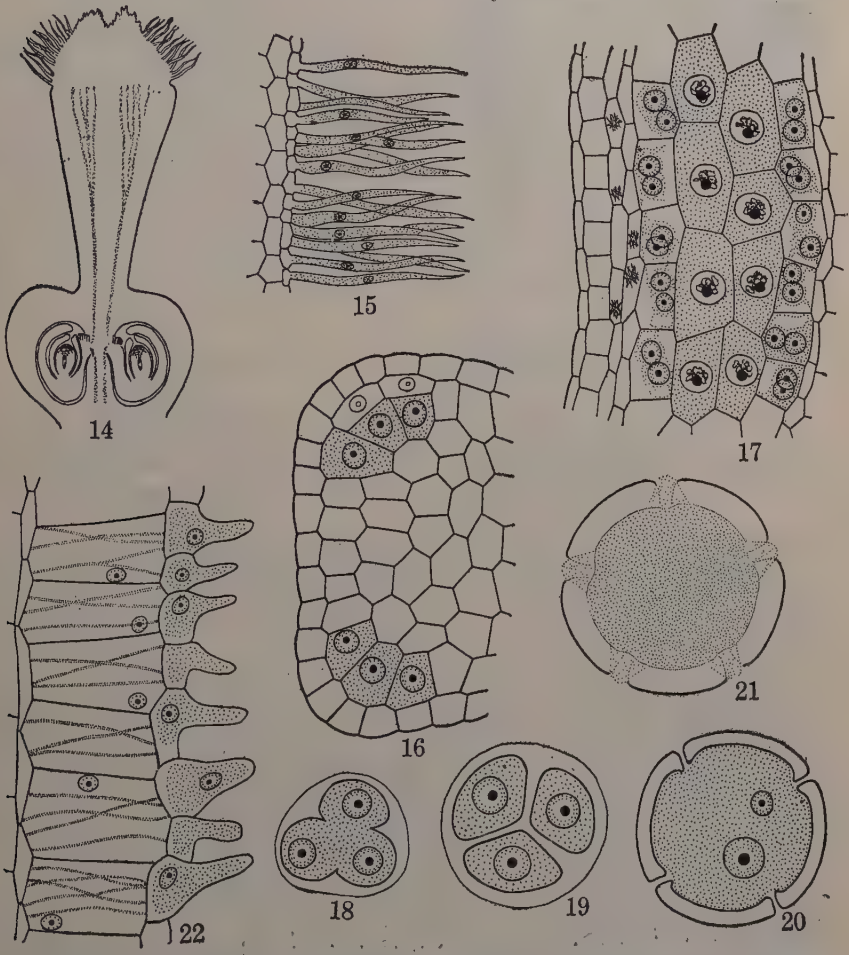
The young anther shows a mass of meristematic cells. As the four-lobed condition becomes evident the primary archesporium is differentiated and it consists of a plate of 3 cells (Fig. 16). These divide periclinally giving rise to a primary parietal layer. The cells of this layer by repeated periclinal and anticlinal divisions give rise to four wall layers (Fig. 17). The innermost of these functions as the tapetum which is of the secretory type (Fig. 17). The cells of the tapetum are uninucleate in early stages and ultimately become 2-nucleate (Fig. 17). Garudamma (1957) reported 2–4 nucleate condition of the tapetal cells in *Melia azadirachta*. Fusion of tapetal nuclei resulting in polyploid nuclei has also been reported in the same species. In *Cipadessa*, however, neither the tapetal cells with more than 2-nuclei, nor cells showing any nuclear fusions have been observed. The cells of the hypodermal wall layer undergo radial elongation and acquire fibrous thickenings and serve as the endothecium (Fig. 22). During the further development of the anther, the tapetal cells become absorbed. An interesting feature is that the epidermal cells of the anther develop papillate outgrowths at about the time the pollen mother cells are undergoing meiotic divisions (Fig. 22). They are best developed by the time the pollen grains are fully formed. Similar epidermal papillæ have been reported in *Melia azadirachta* by Garudamma (1957). Star-shaped crystals resembling druses occur in large numbers mostly in the middle layers which ultimately become crushed.

Meiosis in the pollen mother cells is normal. Cytokinesis takes place by furrowing (Fig. 18). Pollen tetrads are tetrahedral in arrangement (Fig. 19). Pollen grains have a thick, smooth exine. They are 4–5 colporate and are 2-celled at the time of shedding (Figs. 20 and 21). Erdtman (1952) also describes the pollen grains in Meliaceæ as 4–5 colporate.

There is a great degeneration of the pollen mother cells in the several anthers that have been examined.

Ovule, Megasporogenesis and Female Gametophyte

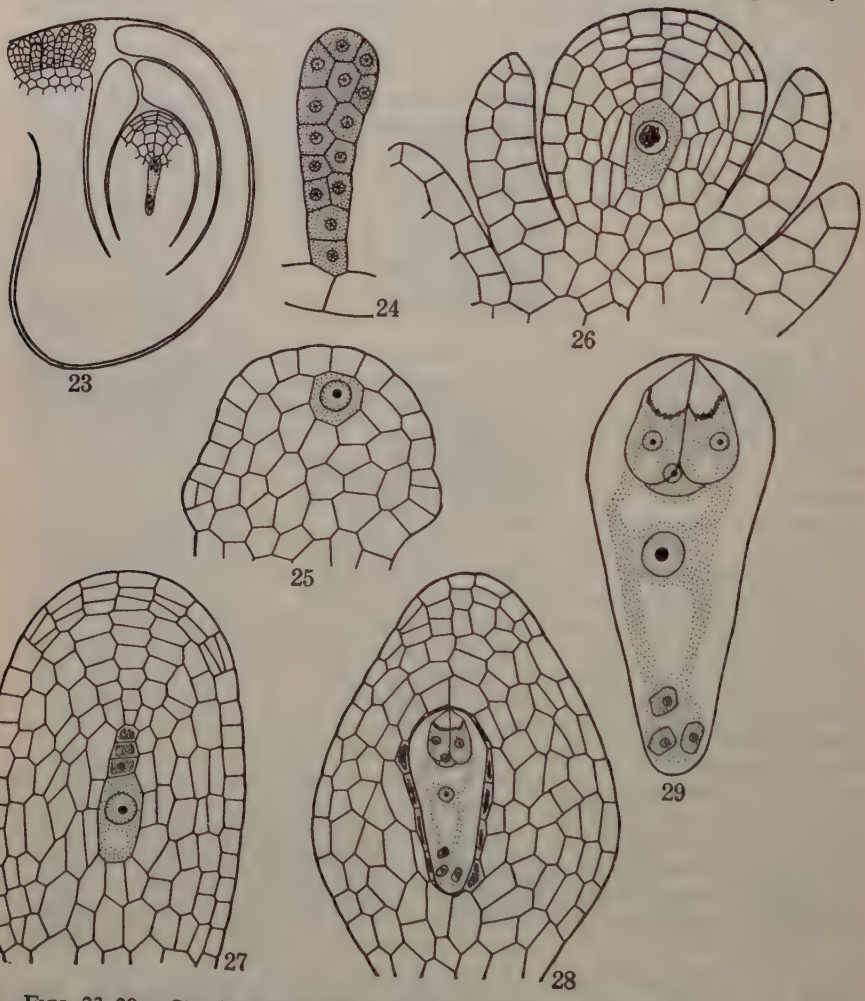
The ovules are crassinucellate, bitegmic and anatropous (Fig. 23). The integuments are free from one another and from the nucellus (Fig. 23). The micropyle is formed by the inner integument alone (Fig. 23). As has already been described the inner margins of the septa of the ovary are lined by multicellular glandular hairs which



FIGS. 14–22. *Cipadessa baccifera* Miq. Fig. 14. *L.S.* of gynœcium showing the course and branching of ventral bundles. Note the hairs in the stigmatic region, ×26. Fig. 15. Stigmatic hairs enlarged, ×246. Fig. 16. *T.S.* half anther showing primary archesporium, ×533. Fig. 17. *L.S.* anther showing epidermis, wall layers, tapetum and pollen mother cells, ×533. Fig. 18. Pollen mother cell showing cytokinesis, ×800. Fig. 19. Pollen tetrad, × 800. Fig. 20. Pollen grain sectional view, ×800. Fig. 21. Pollen grain surface view, ×800. Fig. 22. Papillate epidermis of anther and fibrous endothecium, ×533.

extend downwards and in the placental region form an obturator (Fig. 23).

The primary archesporium in the ovule is single-celled and hypodermal (Fig. 25). A multicellular archesporium has also been observed in some ovules. The primary archesporial cell cuts off a primary



FIGS. 23–29. *Cipadessa baccifera* Miq. Fig. 23. *L.S.* ovule showing obturator and integuments, ×128. Fig. 24. Multicellular hair on the septal margin enlarged, ×800. Fig. 25. *L.S.* ovule showing primary archesporial cell, ×533. Fig. 26. *L.S.* ovule showing megaspore mother cell, parietal cells and integuments. Some of the cells of nucellar epidermis have divided periclinally, ×533. Fig. 27. *L.S.* ovule showing functional megaspore with three degenerating megaspores, parietal cells and cells of nucellar epidermis. Integuments not shown, ×533. Fig. 28. *L.S.* ovule showing mature embryo-sac. Note the crushed parietal and nucellar cells. Integuments not shown, ×533. Fig. 29. Mature embryo-sac enlarged, ×800.

parietal cell, which by repeated divisions gives rise to the parietal layers (Figs. 26, 27 and 28). The cells of the nucellar epiaermis also undergo periclinal divisions and form a cap, which is about 3 layers thick (Figs. 27 and 28). The megaspore mother cell undergoes meiotic division and a linear tetrad of megaspores is formed, of which the lowermost is functional, while the remaining three degenerate during further development (Fig. 27). By three successive free nuclear divisions in the functional megaspore an 8-nucleate embryo-sac is formed (Fig. 23). Thus the development of the embryo-sac follows the normal (*Polygonum*) type. The embryo-sac enlarges during development and as a result of this some of the nucellar cells on the sides and some of the parietal cells above become crushed (Fig. 28). The synergids show at the top a colourless area with a fringed lower margin resembling a filiform apparatus (Figs. 28 and 29). Similar colourless circular areas with fringed margins have been reported in *Pachira aquatica* by Rao (1954). The egg projects only slightly beyond the synergids (Fig. 29). The secondary nucleus lies near the egg apparatus (Fig. 29). The antipodals are organised in the narrow chalazal end of the embryo-sac (Figs. 28 and 29).

Summary and Conclusions

The sepals receive three traces each, a midrib and two laterals. The sepal laterals and the midribs of petals arise conjointly. Each petal receives only a single trace. The traces supplying the perianth divide to form smaller bundles after entering the respective organs.

Ten traces for the ten stamens which unite to form a tube, arise independently from the main stele. The anthers separate from the tube towards the top. The disc which is present between the andrœcium and gynœcium is carried with the staminal tube from which it separates at a higher level.

After the demarcation of the staminal traces five dorsal carpellary traces arise and these divide to form small bundles which ramify near about the central stele. These, however, fade out soon. Branches from the ventrals supply the ovules. After giving off the ovular supply, these continue to the top of the style dividing into numerous small bundles. The stigmatic region is covered with numerous unicellular hairs. Placentation on the basis of floral anatomy is parietal.

The primary archesporium in the anther consists of a plate of three cells. The anther wall consists of an epidermis and four wall layers. The innermost of these functions as the secretary tapetum, the cells of which become 2-nucleate. A fibrous endothecium is developed from the hypodermal wall layer and the middle layers become crushed during the development of the anther. Cytokinesis takes place by furrowing. Pollen tetrads are tetrahedral in arrangement. Pollen grains are 4–5 colporate with a thick smooth exine and are shed at the 2-celled stage.

The epidermal cells of the anther show papillate outgrowths. Druse-like crystals occur in the cells of the wall layers. There is a great degeneration of the pollen mother cells in some anthers.

The ovules are crassinucellate and bitegmic. The micropyle is formed by the inner integument alone. The integuments are free from one another and from the nucellus. A placental obturator is present.

The primary archesporium in the ovule is single-celled and hypodermal. The archesporial cell cuts off a primary parietal cell which by repeated periclinal and anticlinal divisions gives rise to the parietal layers. The cells of the nucellar epidermis also undergo periclinal divisions. The embryo-sac development follows the normal type.

My grateful thanks are due to Prof. J. Venkateswarlu, for suggesting the problem and guidance and to Dr. C. V. Rao and Mr. R. L. N. Sastry for their helpful suggestions. My thanks are also due to Mr. K. Veerabhadra Rao for the material.

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STUDIES ON PIPERACEÆ

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(Received for publication on November 18, 1957)

Introduction

Piperaceæ is a large family consisting of 10 to 12 genera and over 1,300 species distributed in the tropical and sub-tropical regions of the world. It is fairly well distributed in India. Hooker (1885) describes 56 species and 3 genera in two tribes, *Saurureæ* and *Piperaeæ*. Gamble (1925) lists 21 species in three genera, namely *Piper*, *Heckeria* and *Peperomia* in the former Presidency of Madras, while only 18 of them are recorded in Travancore (Rama Rao, 1914).

The family includes several economically important species like *Piper nigrum*, *P. betle*, *P. longum*, etc. The 'black pepper' of commerce is the dried fruit of *P. nigrum*. It is one of the oldest of the spices and used throughout the world for culinary purposes. It has been the main item of trade between India and Europe for centuries, and even to-day forms one of the major export products of India. In view of its very high price and considerable importance in world markets several varieties and forms of *P. nigrum* have been popularised and extensively cultivated in India, especially in Kerala where the climate is well suited for its growth.

Much attention has been paid to the cultivation of other useful plants like *Piper betle* and *P. longum* also, the former for its tender leaves which form the major ingredient of 'pan', and the latter for the spice 'long pepper', which is used as a condiment and also in ayurvedic medicine.

Despite the great economic importance and the wide distribution of a large number of species and varieties of *Piper* and related plants, only very little is known regarding their cytology. As early as 1910 Johnson recorded the chromosome number of *Piper betle*. Johansen (1931) made the haploid and diploid counts of *Piper subpeltatum* (*Heckeria subpeltata* Kunth). Janaki Ammal (1945) reported the chromosome numbers of *Piper nigrum*, *P. betle* and *P. chaba*. Tjio (1948), while studying the somatic chromosome numbers of some tropical plants, determined the chromosome number of *Piper longum*. Maugini (1951) has reported the chromosome numbers of two species of *Piper*, *P. geniculatum* and *P. unguiculatum*. A few other earlier reports on the genus *Peperomia* are mentioned later.

The considerations which prompted the present investigations on the family are: (1) the easy availability of a very large number of distinct varieties, both cultivated and wild, of *Piper nigrum*, and (2) the

desirability of obtaining a clear cytological knowledge of these, which may form a useful guide for future breeding and hybridization work on *Piper*. The study reported here chiefly deals with the number and morphology of the chromosomes of all the available species of *Piper* and related plants indigenous to Kerala, with special reference to the different cultivated and wild varieties of *Piper nigrum*. It embodies observations on four species of *Piper*, one of *Heckeria* and four of *Peperomia*.

Material and Methods

Materials used in this study were collected from different parts of Kerala, and the collections were grown in the Botanical Garden of the University College, and in the Tuber Crop Research Station, Trivandrum. Special attention was paid to the collection of different cultivated and wild varieties of *Piper nigrum*. Most of the cultivated varieties were assembled from Central Travancore. A Malabar variety, known as " Uthirankotta ", was obtained from the Agricultural Research Station, Taliparamba, Malabar. All the wild varieties, except one collected by Prof. Abraham from Waltair, were gathered from places like Ponmudi, Courtallam, Peermade, Parambikulam, etc.

Studies of mitotic chromosomes were made from smears of root tip cells. For this actively growing roots were fixed in Carnoy's fluid (3 : 1 Absolute alcohol-Acetic acid) after pre-treatment with 8-oxyquinoline (30 mg. in 100 ml. water) at 0° C. for 2–3 hours. The use of oxyquinoline was found to be effective in bringing out the morphology of the chromosomes more clearly. Cooling prior to fixation helped to spread out the chromosomes fairly well. A small trace of iron-acetate was added to the fixative and this enhanced the staining capacity of the chromosomes. Slides were prepared according to simple acetocarmine technique. Squashes were made permanent by McClintock's method.

Meiotic chromosomes were studied from pollen mother cells. The fixation adopted was the same as for root tips, but without cooling and pre-treatment in 8-oxyquinoline. Photomicrographs were usually taken from fresh smears, and drawings were made on enlarged photographic prints on smooth matt paper, which were reduced to the desired size in reproduction.

Herbarium sheets of all the plants studied were prepared and are deposited in the Central Herbarium, Kerala University.

Observations

Piper nigrum Linn.

This is a stout glabrous climbing shrub reaching a height of about 30 feet. A large number of distinct varieties, some cultivated and others growing wild, are known. The " black pepper " of commerce is the dried fruit of this species. The chromosome number of *P. nigrum* has been reported to be $2n = $ c. 128 by Janaki Ammal (1945). The present study of the species shows the consistent occurrence of 52

somatic chromosomes in 5 cultivated and 4 wild varieties, and of 104 chromosomes in two of the wild varieties, as detailed below.

Cultivated varieties

As Kerala is the most important pepper growing State in India there are a large number of distinct varieties under cultivation. These are known by separate local Malayalam names. Sometimes the same variety is known by different names in different localities. The local names of a few of the outstanding Malabar as well as Travancore varieties are mentioned below:

Malabar varieties.—" Kalluvally," " Belamkotta," " Cheriakody " and " Uthiramkotta ".

Travancore varieties.—" Narayakodi," " Karimunda," " Kaniakadan," " Kottanadan," " Kumbhakodi," " Karivilanchy," " Perumpettichomala " and " Kuthiravally ".

Most of the above varieties produce perfect flowered spikes and it is seen that the vines producing spikes with predominantly bisexual flowers are the most productive. However, in a Travancore variety known as " Kottanadan " or " Kudaravally "—a female vine—Gentry (1955) observed complete fruit development quite independent of pollination. Although these various varieties show striking differences in their vegetative features as well as in the yield of pepper, the chromosome numbers of all the investigated varieties were found to be the same ($2n = 52$). The chromosomes are very small in size ranging from 1–2·7 μ in length.

Variety No. 1.—This was collected from Palai. The root tip cells showed 52 chromosomes consisting of apparently two pairs of medium sized, six pairs of short and eighteen pairs of shorter chromosomes (Pl. XIII, Fig. 1 and Text-Fig. 1). As the chromosomes were very much condensed the positions of centromeres were not clear.

Variety No. 2.—This was also collected from Palai. Root tip cells showed 52 chromosomes exhibiting more or less the same morphological characters as in variety No. 1.

Variety No. 3.—Root tip cells of this variety, collected from Palai, also showed 52 chromosomes.

Variety No. 4.—This variety, collected from Pallam and locally known as " Narayakodi ", is distinguished by its bushy growth and dark green ovate leaves. The spikes attain a length of about 8–10 centimetres with close-set medium-sized dark green berries. This is a very popular cultivated variety in Central Travancore. Both meiosis and mitosis of this variety were studied. Meiosis takes place when the spikes are about 3 centimetres long. Almost all stages of division were observed in a single spike. In diakinesis the bivalents condense appreciably and are found distributed on the periphery of the nucleus. The number of chiasmata is reduced consequent on terminalization

and some chromosomes are held together only by a single chiasma. Bivalents having two chiasmata show a ring-shaped appearance. In metaphase I the bivalents condense still further and are deeply stained. The nucleolus and the nucleolar membrane disappear and the 26 bivalents move to the centre of the cell and arrange themselves well spaced out (Pl. XIII, Fig. 2 and Text-Fig. 2). The root tip cells of this variety showed 52 small-sized chromosomes.

Variety No. 5.—This was collected from Pathanamthitta. The spikes produced by this variety reached a length of about 20–24 centimetres, the longest so far seen among the cultivated varieties during the present study. The flowers on the spikes are all males and the spikes are all shed a few days after they attain their full growth. Meiosis takes place when the spikes are nearly 5 centimetres long. During meiosis 26 bivalents are observed in pollen mother cells (Pl. XIII, Fig. 3 and Text-Fig. 3).

Wild varieties of Piper nigrum

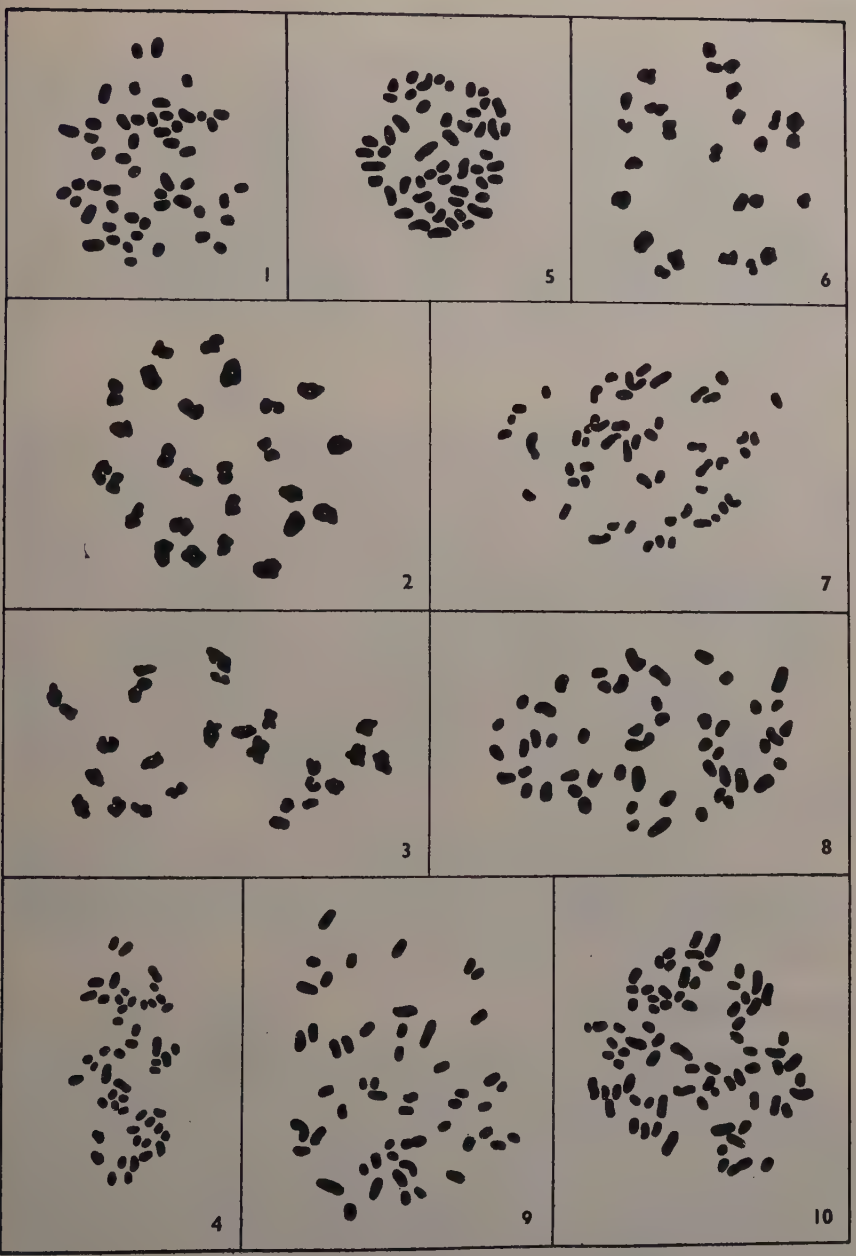
A large number of varieties of *P. nigrum* are found growing wild in the forests of Kerala. Six varieties, collected from places like Ponmudi, Parambikulam, Courtallam, Kumali and Waltair were studied. In four of them the number of somatic chromosomes in root tip cells was $2n = 52$, whereas 104 chromosomes were observed in two varieties, one collected from Kumali (Pl. XIV, Fig. 11 and Text-Fig. 11) and the other from Ponmudi (Pl. XIV, Fig. 12 and Text-Fig. 12). In the wild variety from Courtallam there were two pairs of medium-sized, six pairs of short and eighteen pairs of shorter chromosomes, ranging from 1–3 μ in length (Pl. XIII, Fig. 5 and Text-Fig. 5). In the Waltair variety the chromosomes were found to be slightly smaller in size than those in the other varieties (Pl. XIII, Fig. 4 and Text-Fig. 4). In the Kumali variety with $2n = 104$ there were four pairs of medium-sized, twelve pairs of short and thirty-six pairs of shorter chromosomes, and from this it seems probable that this is an autotetraploid derived from one of the 52-chromosomed wild varieties.

Piper longum Linn.

This is a distinctly diœcious species growing wild in the evergreen forests of the Western Ghats. The 'long pepper' is the product of this species. Tjio (1948), while studying the somatic chromosomes of some tropical plants, counted the chromosome number of this species as $2n = 24$, and this does not agree with the present findings of $n = 26$ and $2n = 52$.

Female plant

The spikes are comparatively much shorter and thicker than that of the male plants. They are cylindrical in shape and about 2–3 centimetres long consisting of female flowers only. The somatic count from root tip cells was clearly $2n = 52$ (Pl. XIII, Fig. 9 and Text-Fig. 9). There were two pairs of medium-sized, six pairs of short and eighteen pairs of shorter chromosomes ranging from 1–3 μ in length.



TEXT-Figs. 1–10. ×1,500. Explanatory diagrams of Figs. 1–10 in Pl.XIII. Fig. 1. *Piper nigrum* cultivated var. 1, $2n = 52$. Figs. 2 and 3. Meiosis in two cultivated varieties of *P. nigrum*, both showing $n = 26$. Figs. 4 and 5. Mitosis in two wild varieties of *P. nigrum*, $2n = 52$. Fig. 6. *P. longum*, $n = 26$. Figs. 7 and 8. *P. longum* male plant, $2n = 52$. Fig. 9. *P. longum* female plant, $2n = 52$. Fig. 10. *P. betle*, $2n = 78$.

Male plant

Mature male spikes reach a length of about 7–9 centimetres. Meiosis takes place when the spikes are nearly 3 centimetres long. During meiosis 26 bivalents were clearly observed in pollen mother cells (Pl. XIII, Fig. 6 and Text-Fig. 6). In root tip cells 52 chromosomes were clearly seen (Pl. XIII, Figs. 7 and 8 and Text-Figs. 7 and 8) and they exhibited more or less the same morphological characters as that of the female. However, of the two pairs of long chromosomes one is an unequal pair with one chromosome slightly larger than the other (see chromosome at 12 O'clock in Fig. 7 and the chromosome in the centre of Fig. 8). The occurrence of this unequal pair was uniformly observed in several preparations.

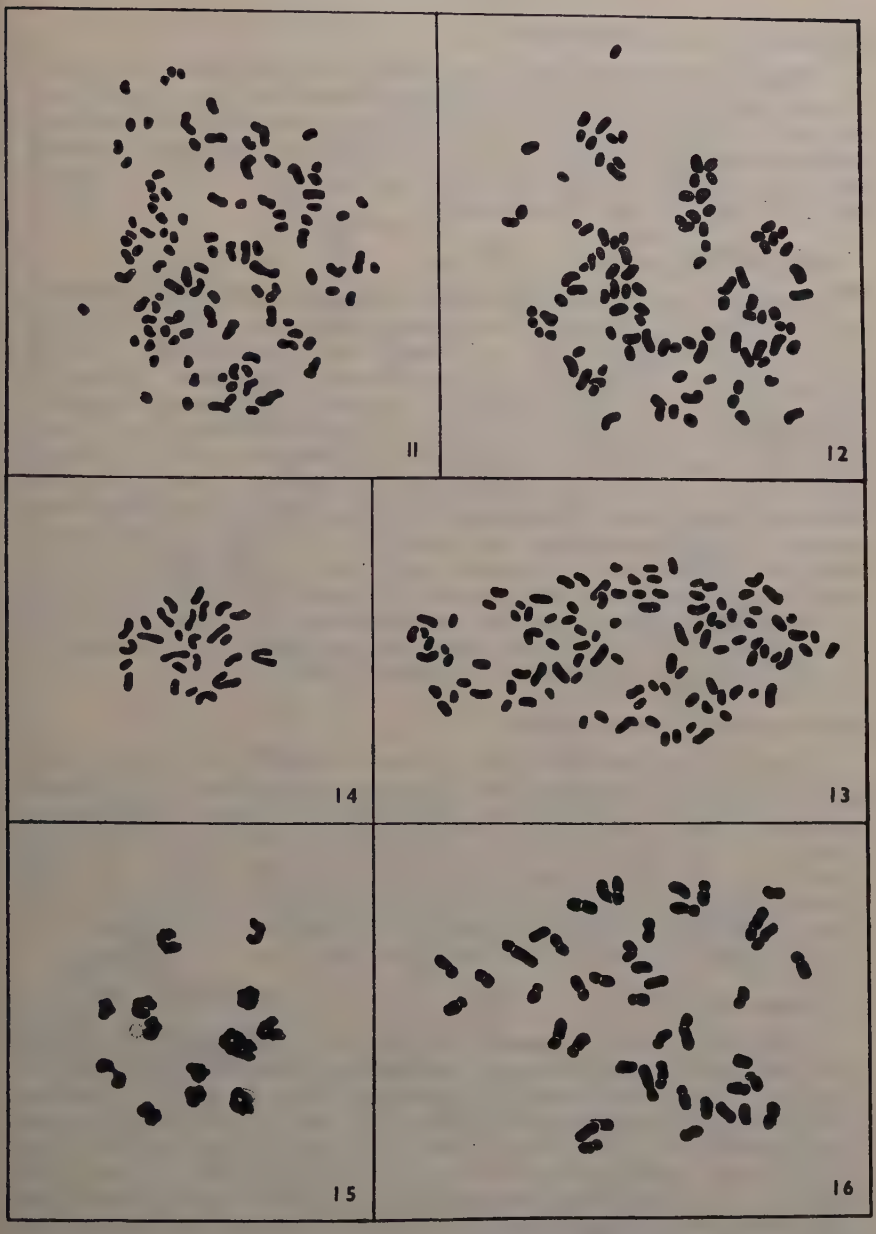
Piper betle Linn.

Tnis is the 'betle pepper' cultivated usually in special trellised gardens for its leaves. The chromosome number of this species has been previously reported as $2n = 32$ by Johnson (1910) and Janaki Ammal (1945). But the present study gave an entirely different count of $2n = 78$ in the root tip cells of two varieties. There were apparently six pairs of medium sized, eight pairs of short and twenty-five pairs of shorter chromosomes (Pl. XIII, Fig. 10 and Text-Fig. 10). Chromosomes were tnick and stout and small-sized, ranging from $1–2 \cdot 7 \mu$ in length. Positions of centromeres could not be recognized clearly except in a few of the longer ones, where it is nearly median or submedian. From an analysis of the chromosome numbers of other species of *Piper* it is suggested that *P. betle* is a triploid. However, this plant cultivated for its leaves has not been seen in flower in Kerala, and so it was not possible to study its meiosis.

Another species of *Piper* (undetermined), collected from Mahendragiri forest in Kanyakumari District was found to possess 104 chromosomes in its root tip cells. Somatic complement consisted of four pairs of medium-sized, sixteen pairs of short and thirty-two pairs of shorter chromosomes (Pl. XIV, Fig. 13 and Text-Fig. 13).

Heckeria subpeltata Kunth.

Materials from two localities, Ponmudi and Courtallam, have been studied. The haploid chromosome number observed during meiosis in pollen mother cells was clearly $n = 13$ (Pl. XIV, Fig. 15 and Text-Fig. 15). The somatic number in root tip cells was $2n = 26$ (Pl. XIV, Fig. 14 and Text-Fig. 14). Chromosomes were found to be comparatively thinner and longer than those in species of *Piper* and they varied from $1 \cdot 3$ to $4 \cdot 3 \mu$ in length. Of the 13 pairs, one was found to be considerably longer than the rest. This plant has been previously studied by Johansen (1931) who reported its chromosome number as $2n = 24$.



TEXT-FIGS. 11–16. ×1,500. Explanatory diagrams of Figs. 11–16 in Pl. XIV. Figs. 11 and 12. Two wild varieties of *Piper nigrum* with $2n = 104$. Fig. 13. Mitosis in an undetermined species of *Piper*, $2n = 104$. Fig. 14. *Heckeria subpeltata*, $2n=26$. Fig. 15. *H. subpeltata*, $n = 13$. Fig. 16. *Peperomia portulacoides*, $2n = 44$.

Peperomia portulacoides Dictr.

This is a small herbaceous plant growing epiphytically on the trunks of trees, and its cytology has been studied for the first time. In the root tip cells of materials collected from Ponmudi there were 44 chromosomes, consisting of three pairs of medium-sized, ten pairs of short and nine pairs of shorter members, ranging from 2–4 μ in length (Pl. XIV, Fig. 16 and Text-Fig. 16).

P. pellucida H. B. and K.

This is a small herbacceous plant available locally in Trivandrum. During meiosis 22 bivalents were clearly observed in pollen mother cells at first metaphase (Pl. XV, Fig. 18 and Text-Fig. 18). Pairing of homologous chromosomes and subsequent anaphase separation were regular and normal division followed. The somatic number counted from root tip cells was $2n = 44$ (Pl. XV, Fig. 17 and Text-Fig. 17). They are fairly large-sized ranging from 3 to 6 μ in length and consisted of two pairs of short chromosomes. It may be noted that the chromosomes of this species are larger than those of any other species in the Piperaceæ so far examined. Attachment constrictions were clearly seen in all and according to their position there are four pairs of chromosomes with median, thirteen pairs with submedian and five pairs with subterminal constrictions. The present findings of $n = 22$ and $2n = 44$ in this species do not agree with the count of $2n = 24$ reported previously by Johnson (1914).

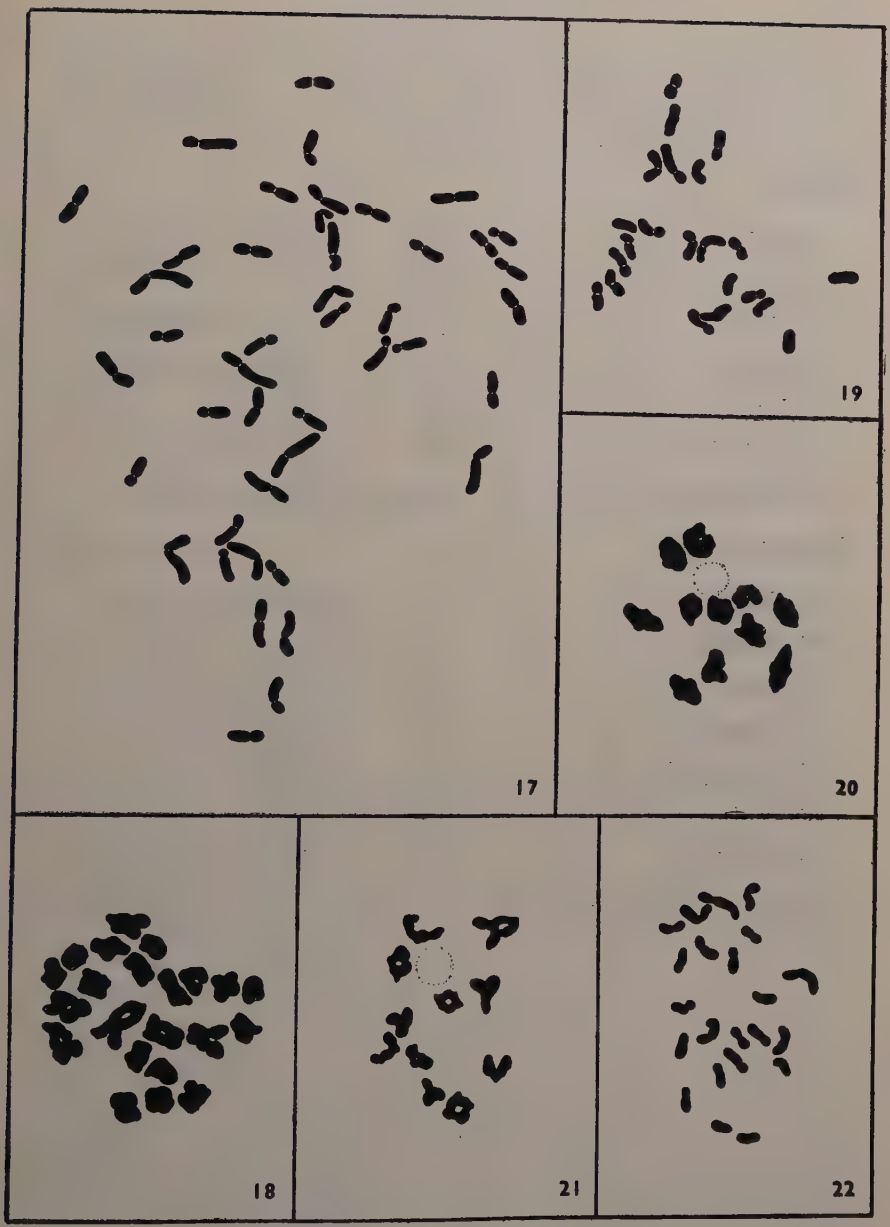
Peperomia sp. (undetermined)

This is an introduced plant grown in gardens and having very thick dark green obovate leaves and long spikes about 20–25 centimetres. Meiosis takes place when the spikes are nearly 3–4 centimetres long. The number of bivalents observed in pollen mother cells was clearly 11 (Pl. XV, Fig. 20 and Text-Fig. 20). Root tip cells showed 22 chromosomes consisting of one pair of medium-sized, four pairs of short and six pairs of shorter chromosomes varying from 2·3–4·3 μ in length (Pl. XV, Fig. 19 and Text-Fig. 19).

P. sandersii C.D.C.

This is a South American species indigenous to Brazil. It has been introduced into India as a garden plant because of its beautiful foliage. Material for study was obtained from the Public Gardens, Trivandrum. During meiosis 11 bivalents were clearly seen in pollen mother cells (Pl. XV, Fig. 21 and Text-Fig. 21) and double this number was observed in root tip cells (Pl. XV, Fig. 22 and Text-Fig. 22). The diploid set consisted of one pair of medium-sized, two pairs of short and eight pairs of shorter chromosomes. Their length ranged from 2·3–5 μ.

The following list has been compiled from the chromosome counts previously reported and also those made during the present investigation on the Piperaceæ.



TEXT-FIGS. 17–22. ×1,500. Explanatory diagrams of Figs. 17–22 in Pl. XV. Fig. 17. *Peperomia pellucida*, $2n = 44$. Fig. 18. *P. pellucida*, $n = 22$. Fig. 19. Mitosis in an undetermined species of *Peperomia*, $2n = 22$. Fig. 20. Meiosis in the same species as above showing $n = 11$. Fig. 21. *P. sandersii*, $n = 11$. Fig. 22. *P. sandersii*, $2n = 22$.

PREVIOUS REPORTS

Species	2*n* number	Author
PIPER		
P. betle	32	Johnson (1910)
P. betle	32	Janaki Ammal (1945)
P. chaba	24	Janaki Ammal (1945)
P. nigrum	c.128	Janaki Ammal (1945)
P. longum	24	Tjio (1948)
P. geniculatum ..	28	Maugini (1951)
P. unguiculatum ..	28	Maugini (1951)
PEPEROMIA		
P. sintenisii	16	Brown (1908)
P. pellucida	24	Johnson (1914)
P. resediflora	24	Hauser (1916)
P. metallica	24	Abele (1923)
P. verschaffeltii ..	24	Abele (1923)
P. sandersii	24	Suguira (1936)
P. maculosa	44	Martinoli (1948)

PRESENT STUDY

Name of plant	Locality	Chromosome No. *n*	Chromosome No. *2n*	Basic No.
PIPER				
P. nigrum (Cultivated varieties)				
Var. 1	Palai	..	52	13
Var. 2	Palai	..	52	13
Var. 3	Palai	..	52	13
Var. 4	Pallam	26	52	13
Var. 5	Pathanamthitta	26	52	13
(Wild varieties)				
Var. 1	Ponmudi	..	52	13
Var. 2	Parambikulam	..	52	13
Var. 3	Courtallam	..	52	13
Var. 4	Waltair	..	52	13
Var. 5	Kumali	..	104	13
Var. 6	Ponmudi	..	104	13
P. longum				
Male plant	Courtallam	26	52	13
Female plant	Courtallam	..	52	13
P. betle	Kottayam	..	78	13
Piper sp.	Mahendragiri	..	104	13
HECKERIA				
H. subpeltata	Courtallam	13	26	13
PEPEROMIA				
P. portulacoides	Ponmudi	..	44	11
P. pellucida	Trivandrum	22	44	11
Peperomia sp.	Madras	11	22	11
P. sandersii	Trivandrum	11	22	11

Discussion

Basic chromosome numbers in the Piperaceæ

From the list given above it may be seen that the previously reported chromosome numbers in the genus *Piper* are $2n = 24$, 28, 32 and c. 128. But an apparently very different set of chromosome numbers has been observed during the present study of the South Indian species of *Piper*. They are $n = 26$ and $2n = 52$ as in a number of cultivated and wild varieties of *P. nigrum* and in *P. longum*, $2n = 78$ as in *P. betle* and $2n = 104$ as in two of the wild varieties of *P. nigrum* and in the undetermined species of *Piper* from Mahendragiri. It is worth noting that these numbers follow a strict arithmetical progression and all of them can be directly traced down to a common basic number 13. These South Indian representatives of *Piper* thus appear to constitute a uniform group with a common basic number 13, which is reported for the first time in the family *Piperaceæ*. In view of the fact that very clear preparations of both mitosis and meiosis have been obtained of all the species of *Piper* reported in the present study, and as they all have chromosome numbers in multiples of 13, one may be justified in doubting the accuracy of the earlier observations on the same species. However, I am not excluding the possibility that lower numbers may have existed in the genus *Piper* at an earlier stage in evolution, with a few surviving species in certain geographical regions still retaining multiples of numbers like 6 and 7. For, it is probable that a number like $n = 13$ may have arisen by inter-specific hybridization between types with $n = 6$ and $n = 7$ followed by doubling of the chromosomes of the hybrid.

Regarding the genus *Heckeria*, which is represented in South India by only a single species, *H. subpeltata* ($n = 13$ and $2n = 26$), it may be seen that the same basic number 13, as in *Piper*, is prevalent in this genus also. This does not, however, agree with the previous count of $n = 12$ made by Johansen (1931) in *Piper subpeltatum* (*Heckeria subpeltata* Kunth.). The existence in both *Piper* and *Heckeria* of the same basic chromosome number 13, is of some importance when the systematic treatment of the latter is taken into consideration. Taxonomists like Hutchinson (1926) and Hooker (1885) have described *Heckeria subpeltata* as a species of *Piper* (*Piper subpeltatum*), while Gamble (1925), from a purely morphological point of view, recognizing the difference in the habit of the plant and the more specialized floral structure it exhibits, has tried to isolate the plant from the genus *Piper* and treated it in a separate genus. The cytological resemblance in having a common basic number cannot alone justify the inclusion of *Heckeria subpeltata* in the genus *Piper*. When the chromosomes of *Piper* and *Heckeria* are studied on a comparative basis, it is seen that they differ in their size and morphology. In all the species of *Piper*, chromosomes are roundish and very small sized, ranging from 1–3 μ in length, whereas in *H. subpeltata* the chromosomes are comparatively thinner and longer (1·3–4·3 μ). This difference in the size and shape of the chromosomes taken with significant morphological differences appears to provide

support in favour of Gamble's separation of *H. subpeltata* from the genus *Piper*.

Previously investigated species of *Peperomia* show three different chromosome numbers, $2n = 16$, 24 and 44 which are multiples of different basic numbers. But in the present report all the investigated species have chromosome numbers ($2n = 22$ and 44) in multiples of the same number, 11. The disparities noted in the earlier sections regarding chromosome numbers in *Piper* and *Heckeria* lead one to doubt in the case of *Peperomia* also the accuracy of some of the previous reports. This is especially strongly felt as in the present investigation introduced species of *Peperomia* also have been studied and in all of them the chromosome numbers are found to be clearly in multiples of 11, though such a number ($2n = 44$) has been reported previously only in *Peperomia maculosa* (Martinoli, 1948). Therefore, it is taken that the basic number in this genus is 11.

Polyploidy in Piperaceæ

The present investigations on the family Piperaceæ have shown that *Piper* and *Peperomia* are two distinct genera having chromosome numbers based on two different basic numbers, 13 and 11 respectively. Though only four species of *Piper* have been studied it is interesting to note that three chromosome numbers, $2n = 52$, 78 and 104, are found occurring in them. These higher numbers, all of which are in exact multiples of the common basic number 13, indicate the significance of polyploidy in the evolution of species in *Piper*. However, it is a fact that no species with $2n = 26$ has hitherto been met with in this genus. In the absence of such a species, 26 may have to be tentatively taken as the existing lowest haploid number of the genus, thereby making the 52-chromosomed varieties of *P. nigrum* and *P. longum* diploids, *P. betle* ($2n = 78$) triploid and the 104-chromosomed wild varieties of *P. nigrum* and the undetermined species of *Piper* with $2n = 104$ tetraploids. As the meiosis of these triploid and tetraploid species have not been studied, further comment on this aspect is not possible. However, from a comparative study of the morphology of the chromosomes of both the diploid and tetraploid varieties of *P. nigrum* it has been suggested that the latter is apparently an auto-tetraploid derived from one of the 52-chromosomed wild varieties of *P. nigrum*. The approximate count of $2n =$ c. 128 reported in *P. nigrum* by Janaki Ammal (1945) is of some interest in this connection. In the light of a detailed study, made of several varieties of *P. nigrum*, all showing chromosome numbers in multiples of 13, we are sufficiently justified in considering the correct chromosome number of her material as probably $2n = 130$, which is again a multiple of 13. If this is accepted the material examined by her must have been a pentaploid. Thus, the occurrence in *P. nigrum* of different chromosome numbers, $2n = 52$, 104 and 130, all in multiples of the same number, gives an instance of intra-specific polyploidy in this species.

Of the four investigated species of *Peperomia*, two were diploids with $2n = 22$ and the other two, namely, *P. pellucida* and *P. portula-*

coides, both with $2n = 44$, were tetraploids on the basic number 11. In *P. pellucida* meiosis was normal with regular pairing resulting in the formation of bivalents only, and this indicates that it is an allotetraploid species. A still higher grade of polyploidy was noticed in another species of *Peperomia* (not included in this report) which showed a somatic count of $2n = 66$. This is a hexaploid species with the same basic number 11. Thus, the occurrence in *Peperomia* of chromosome numbers like $2n = 22$, 44 and 66, constituting a polyploid series, shows that in this genus also, as in *Piper*, polyploidy with little change in basic chromosome number has been operative in speciation.

Sex chromosomes in Piper longum

This is a distinctly diœcious species with the female plants producing very short spikes bearing female flowers only, and the males producing very long spikes, several times the length of the female spikes, carrying male flowers only. So it has been interesting to enquire whether the existing morphological differences in spikes and flowers between the sexes could be correlated with any readily recognizable chromosomal differences. Tjio (1948), who has reported the cytology of this species does not seem to have paid any special attention in this direction. He counted 24 somatic chromosomes, of which two, with the asymmetric arms, were longer than the rest. Two of the smaller ones had very pronounced constrictions. The present study of the species gave a somatic count of $2n = 52$ in both sexes. From a comparative study of several somatic complements from both male and female plants it was found that the males possessed a pair of heteromorphic chromosomes. In one of the two long pairs of chromosomes in the somatic complement of the male it is found that one chromosome is always slightly longer than the other. The smaller chromosome of the pair is of the same size as the two pairs of long chromosomes of equal size found in the female also. Although the difference in length between the members of this unequal pair is not so very marked as in some of the diœcious plants like *Coccinia indica* (Kumar and Vishveshwaraiah, 1952), the consistent occurrence of this heteromorphic pair in all the somatic complements of the male plant examined would strongly suggest that in *P. longum* the male is heterogametic with XY type of sex chromosomes, the Y being longer than the X. The female is homogametic (XX).

Summary

1. Cytology of nine species belonging to three South Indian genera, *Piper*, *Heckeria* and *Peperomia* has been studied. The chromosome number and morphology are given for all the species studied.

2. The chromosome numbers in the genus *Piper* are:—$n = 26$ and $2n = 52$ in five cultivated varieties, $2n = 52$ in four and $2n = 104$ in two of the wild varieties of *P. nigrum*, $n = 26$ and $2n = 52$ in *P. longum*, $2n = 78$ in *P. betle* and $2n = 104$ in an undetermined species of *Piper*.

3. These numbers, all in multiples of the basic number 13, are reported for the first time in Piperaceæ. In the absence of a species of *Piper* with $2n = 26$, the lowest haploid number for the genus *Piper* is taken as 26.

4. *Heckeria subpeltata* gave a haploid count of $n = 13$ and a diploid count of $2n = 26$.

5. *Peperomia* showed two chromosome numbers $n = 11$ and $2n = 22$ as in *P. sandersii* and also in an undetermined species of *Peperomia*, while *P. pellucida* and *P. portulacoides* showed $2n = 44$.

6. From a discussion of the cytological data it is suggested that 13 and 11 are the basic chromosome numbers existing among the South Indian representatives of the family, 13 in *Piper* and *Heckeria* and 11 in *Peperomia*.

7. Role of polyploidy in Piperaceæ is briefly considered, and it is suggested that this has been an important factor in the evolution of species in *Piper* and *Peperomia*.

8. Sex chromosomes are observed in the diœcious species, *Piper longum*, the male being the heterogametic sex with XY type of sex chromosomes, where Y is longer than X. The female is homogametic with XX sex chromosomes.

Acknowledgement

This investigation was carried out under the supervision of Professor A. Abraham, Head of the Department of Botany, Kerala University. I am deeply indebted to him for his valuable guidance and encouragement and for the keen interest he took in the progress of this investigation.

My thanks are also due to the Ministry of Education, Government of India, for the award of a Junior Research Scholarship. I am thankful to the University of Kerala for the excellent Research facilities.

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* *Vide* Darlington, C. D. and Wylie, A. P. (1955).

EXPLANATION OF PLATES

PLATE XIII

FIGS. 1–10. All photographs at a magnification of ×1,320.

FIG. 1. Somatic mitosis in root tip cells of *Piper nigrum*, cultivated variety No. 1 showing $2n = 52$.

FIG. 2. Meiosis in pollen mother cells of *P. nigrum*, cultivated variety No. 4, showing 26 bivalents at metaphase I.

FIG. 3. Meiosis in *P. nigrum*, cultivated variety No. 5, showing 26 bivalents.

FIG. 4. Mitosis of *P. nigrum*, wild variety from Waltair, showing 52 chromosomes in root tip cells.

FIG. 5. Mitosis in another variety of *P. nigrum* from Courtallam showing 52 chromosomes in root tip cells.

FIG. 6. Meiosis in pollen mother cells of *P. longum* showing 26 bivalents at metaphase I.

FIGS. 7 & 8. Root tip squash preparations of *P. longum* male plant showing $2n = 52$.

FIG. 9. Mitosis of *P. longum* female plant showing 52 chromosomes in root tip cells.

FIG. 10. Somatic mitosis in root tip cells of *P. betle* showing 78 chromosomes.

PLATE XIV

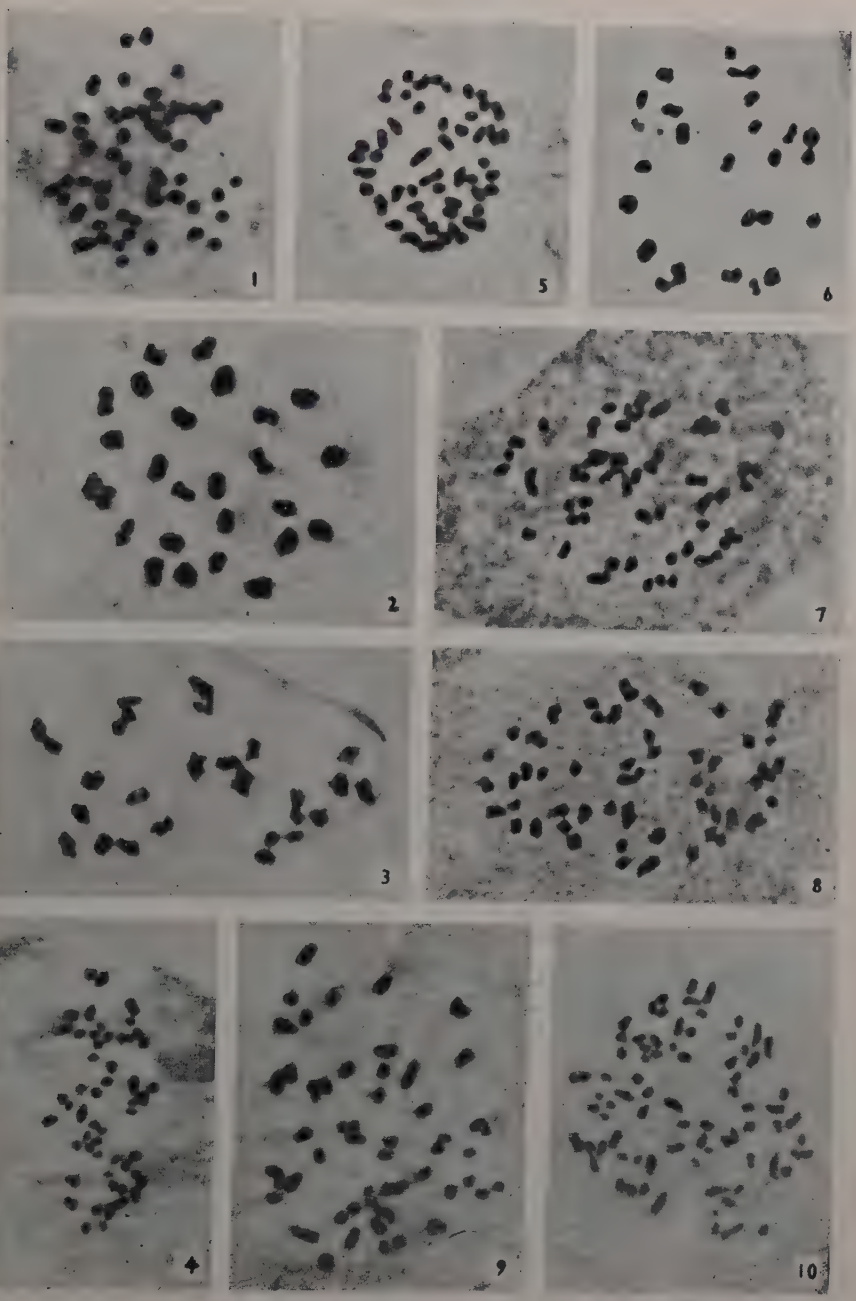
FIGS. 11–16. All photographs at a magnification of ×1,320.

FIG. 11. Somatic mitosis in root tip cells of a wild variety of *Piper nigrum* from Kumali showing $2n = 104$.

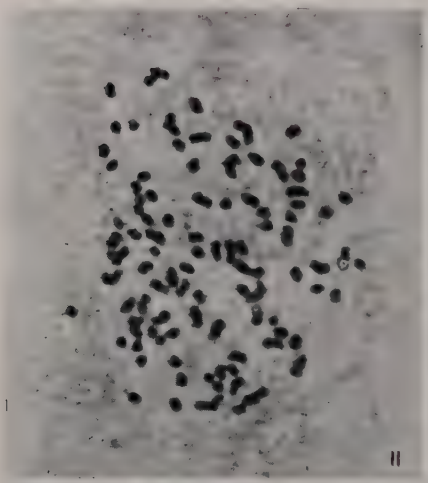
FIG. 12. Mitosis in another wild variety of *P. nigrum* from Ponmudi showing $2n = 104$.

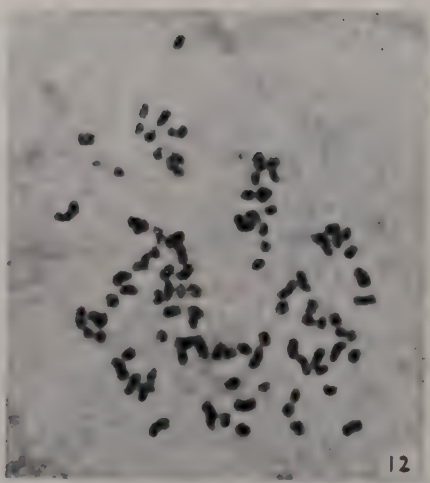
FIG. 13. Root tip mitosis in an undetermined species of *Piper* from Mahendragiri showing clearly $2n = 104$.

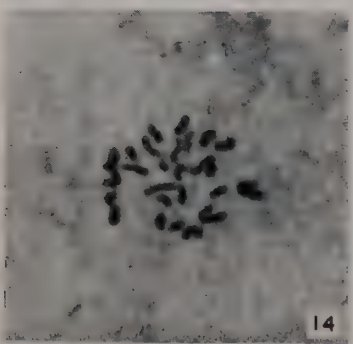
FIG. 14. Mitosis in root tip cells of *Heckeria subpeltata* clearly showing 26 chromosomes.

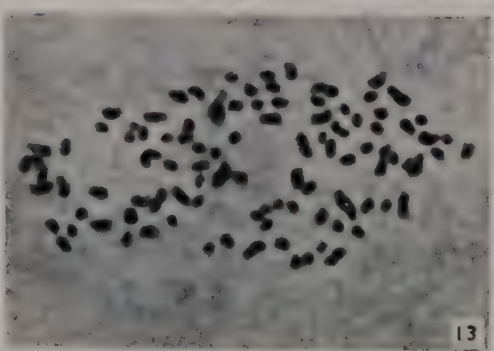


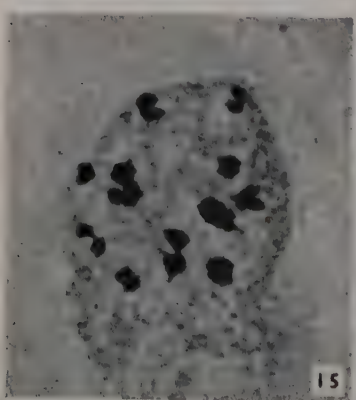
P. M. Mathew

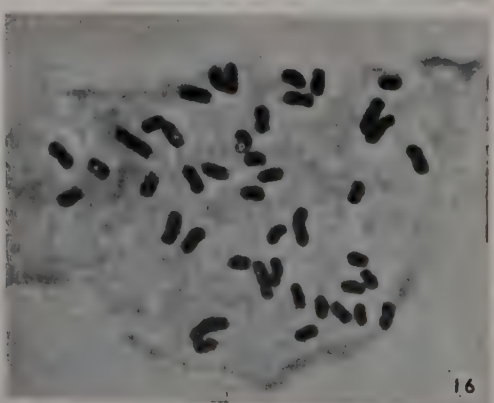












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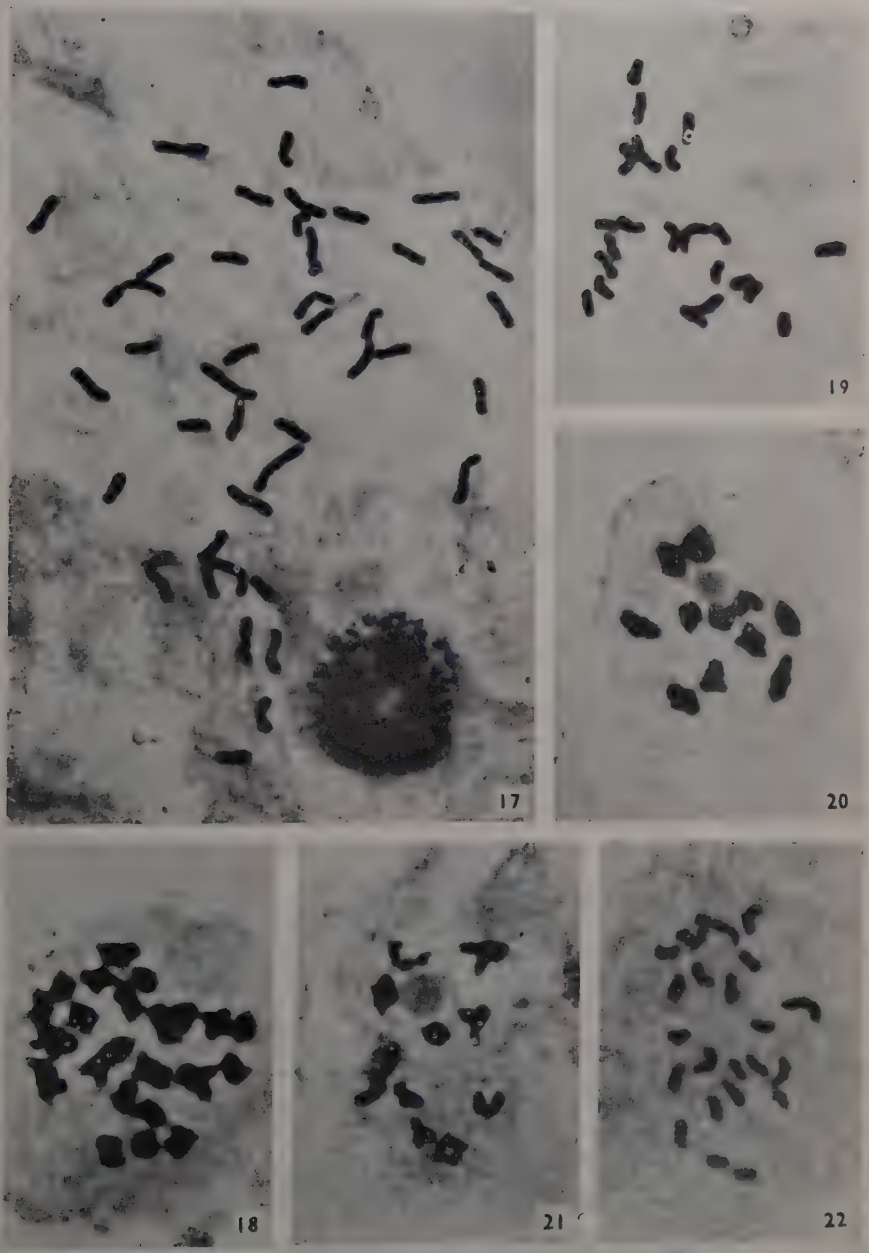

P. M. Mathew

FIG. 15. Meiosis in *H. subpeltata* showing 13 bivalents in pollen mother cells.

FIG. 16. Root tip squash of *Peperomia portulacoides* showing 44 chromosomes.

PLATE XV

FIGS. 17–22. All photographs at a magnification of ×1,320.

FIG. 17. Mitosis in root tip cells of *Peperomia pellucida* showing 44 chromosomes.

FIG. 18. Meiosis of *P. pellucida* showing 22 bivalents in pollen mother cells at metaphase I.

FIG. 19. Mitosis in root tip cells of an undetermined species of *Peperomia* showing $2n = 22$.

FIG. 20. Meiosis in the above species showing 11 bivalents.

FIG. 21. Meiosis of *P. sandersii* showing 11 bivalents in pollen mother cells.

FIG. 22. Root tip squash of *P. sandersii* showing 22 chromosomes.

VASCULAR ANATOMY OF THE FLOWER OF SOME SPECIES OF ZYGOPHYLLACEAE

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(Received for publication on November 19, 1957)

Introduction

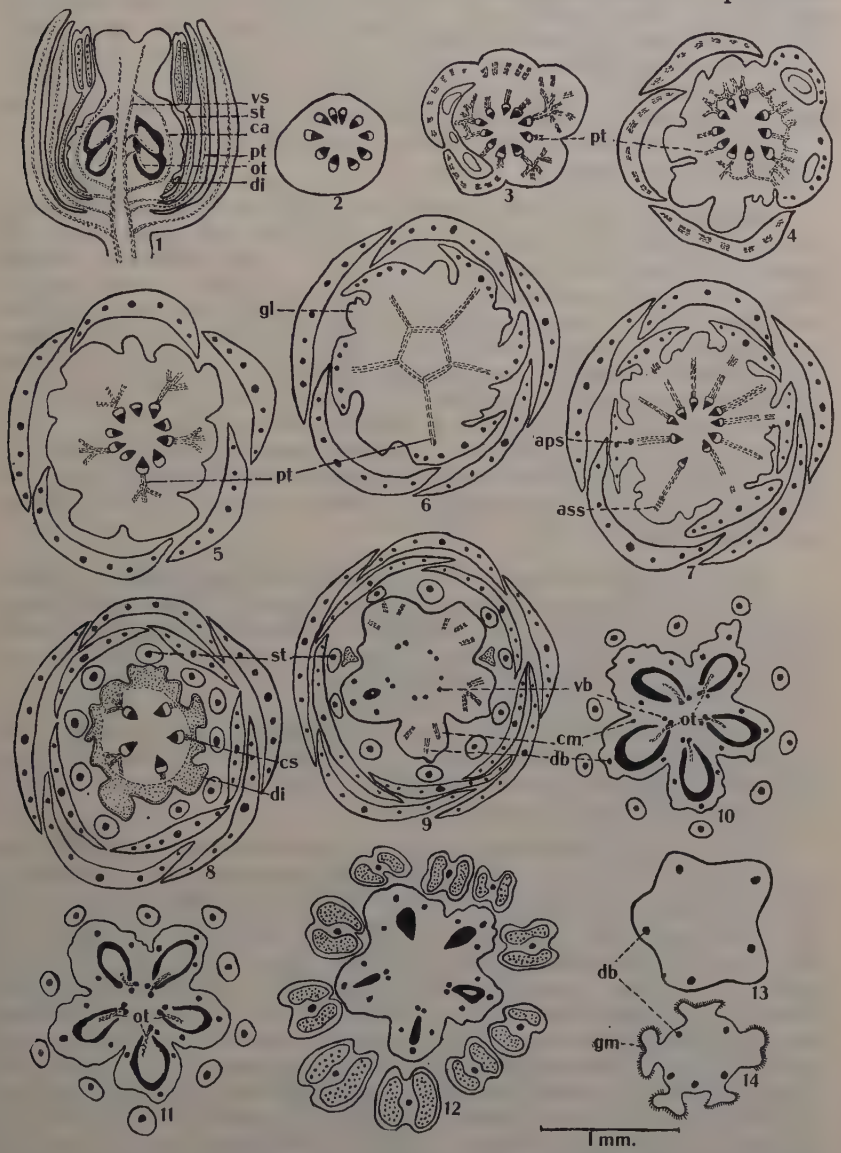
Floral anatomy of the predominantly tropical family Zygophyllaceæ is little known. Saunders (1937) described the vascular anatomy of *Zygophyllum falago*, *Tribulus terrestris*, *Peganum harmala* and *Guaiacum officinale* and in accordance with her theory of carpel polymorphism interpreted each vascular bundle of the ovary to be the supply of a carpel. Recently Shukla (1955) described certain interesting abnormalities in the flowers of *Peganum harmala*. In the present paper the vascular anatomy of the flowers of *Tribulus terrestris* Linn., *T. alatus* Linn., *Fagonia arabica* Linn., *F. mollis* Del., *Peganum harmala* Linn., *Zygophyllum dumosum* Linn., *Z. simplex* Linn., and *Nitraria retusa* (Forsk.) Asch. is dealt with in a comparative manner.

Of the eight species, only *Tribulus terrestris* and *Fagonia arabica* were collected locally. *Tribulus alatus* and *Peganum harmala* were procured from Shri Ganga Nagar. Herbarium materials of the rest of the species were obtained by the kindness of Dr. A. Fahn, Hebrew University, Jerusalem. Fresh material was fixed in formalin-acetic-alcohol. Herbarium material was treated with three per cent. potassium hydroxide at 50° C. for six hours, then washed in water for an equal length of time and fixed in formalin-acetic-alcohol. Dehydration and embedding were done in the usual way. Sections were cut 10–12 microns thick. Fresh material was stained in erythrosin and crystal violet while herbarium materials gave good results only with safranin and fast green. The observations are based on a minimum of fifteen flowers in the case of herbarium materials and thirty in the case of fresh flowers.

Observations

External Morphology.—The flowers are dichlamydeous, actinomorphic, perfect, and pentamerous. The free sepals are either imbricate (*Tribulus*, *Nitraria*, *Zygophyllum*) or valvate (*Fagonia* and *Peganum*). In *Tribulus*, *Nitraria* and *Zygophyllum* they are turned downwards for a greater or less distance from the point of origin (Fig. 1). Petals are spathulate and imbricate (*Tribulus*) or twisted (*Peganum*, *Fagonia*) or valvate (*Nitraria*, *Zygophyllum*). The stamens are in two whorls of five each except in *Peganum* and *Nitraria* where fifteen stamens are arranged in five groups of three, opposite each sepal. The filament in *Zygophyllum* has a bilobed scale at the base and in *Tribulus* the filament of

the antisepalous stamen is provided with a bilobed gland. Anthers are introrse and dithecous. Within the staminal whorl is a prominent



FIGS. 1–14. *Tribulus alatus*. (*aps*, antipetalous staminal trace; *ass*, antisepalous staminal trace; *ca*, ovary wall supply; *cm*, secondary marginal bundle; *cs*, carpellary supply; *db*, dorsal bundle; *di*, disc; *gl*, gland; *gm*, commissural stigma; *ot*, ovular trace; *pt*, petal trace; *st*, stamen; *vb*, ventral bundle; *vs*, placental supply). Fig. 1. L.S. flower (semi-diagrammatic). Figs. 2–14. Serial transections from pedicel upwards.

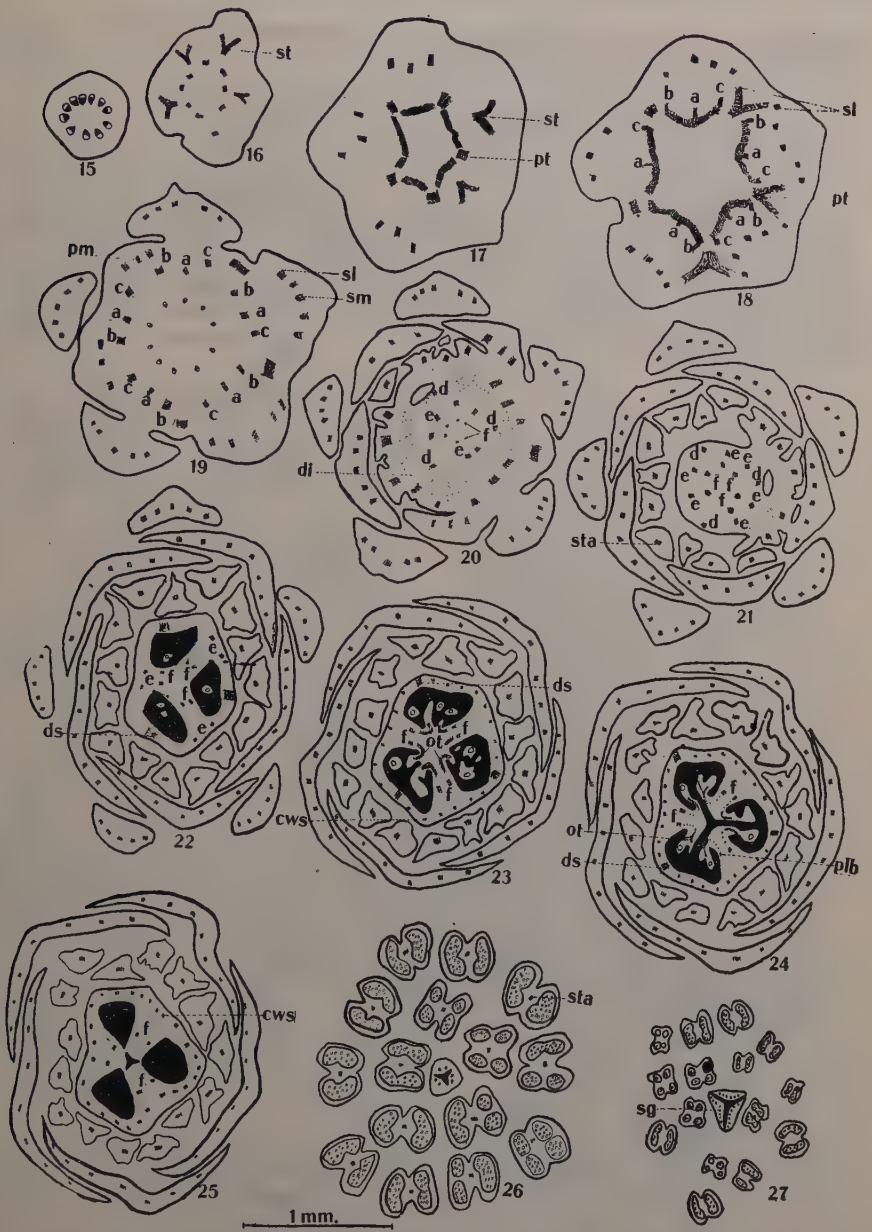
lobed disc. The gynœcium, except in *Peganum* and *Nitraria* where it is tricarpellary, is pentacarpellary. It is multilocular in *Tribulus*, *Fagonia* and *Nitraria*. In *Peganum* and *Zygophyllum* the placentas recede to the periphery in the middle making it unilocular. The style, which is very short in *Tribulus*, terminates in as many stigmatic branches as there are carpels. In the number of ovules a reduction series can be seen ranging from a large number to a single ovule per carpel. There is a lobed stylar canal lined with transmitting tissue and each lobe corresponds to a carpel.

Vascular Anatomy.—The vascular tissue in the pedicel consists of a ring of bundles separated by narrow medullary rays (Figs. 2, 15, 40) except in *Zygophyllum* and *Fagonia* where it is an unbroken cylinder (Figs. 29, 53). The calyx supply in *Nitraria retusa* consists of a whorl of five traces. Each trace, soon after its origin, divides into three (Fig. 42). In *Zygophyllum* species each sepal receives three traces, a median arising directly from the receptacular stele and two laterals arising from the petal strands (Figs. 54, 55). *Peganum harmala* is essentially similar except the median trace divides into three soon after its origin so that a sepal receives five traces. *Tribulus* species differ from *Peganum*; here the sepal median shows branching and fusion of traces (Figs. 3, 4). The calyx supply in *Fagonia* species consists of median and commissural traces (Figs. 30, 31).

Below the origin of petal traces the stele becomes closed in *Peganum* and *Nitraria*. The petal trace divides into three, in the receptacular cortex as in *Nitraria* (Figs. 43, 44) or at the base of the petal in *Tribulus* (Figs. 5, 6), *Zygophyllum* (Figs. 55, 56), and *Peganum* (Figs. 18, 19), or at higher regions of the petal in *Fagonia*.

In *Zygophyllum* the bilobed scale at the base of the filament is composed of homogenous parenchyma. Neither this scale nor the gland in *Tribulus* receive any vascular tissue. These structures are stipular in nature without any vascular tissue.

At a region close below the level of staminal traces, the stele becomes closed in *Tribulus*, *Nitraria* and *Zygophyllum*. The supplies to the antipetalous stamens arise earlier than the antisepalous ones. In three genera *Tribulus*, *Peganum* and *Zygophyllum*, the supplies to both the whorls of stamens arise independently (Figs. 6, 18, 57). The antipetalous staminal traces in other genera show adnation with petal traces. In *Peganum harmala* at each of the outer angles of the gaps formed by the petal traces there diverges out a trace to the lateral stamens of the triplet. The next whorl of five traces given out on sepal radii supply the middle stamens of the triplets (Figs. 18–20). *Nitraria retusa* closely resembles the pattern of *Peganum harmala* except for the fact that the supplies to the lateral stamens of the triplet are derived from petal laterals (Figs. 43–44). The petal traces in *Fagonia* species divide tangentially into two parts, the inner supplying the outer antipetalous whorl of stamens while the outer enter the petals (Figs. 32–34). In *Peganum harmala* the cortex of the staminal filament shows large airspaces (Fig. 28). The filament has a concentric vascular bundle at



FIGS. 15–27. *Peganum harmala*. (*a*, supply to median stamen; *bc*, supply to lateral stamens; *cws*, ovary wall supply; *di*, disc; *ds*, dorsal; *e*, secondary marginal; *f*, ventral bundle; *ot*, ovular trace; *plb*, placental bundle; *pt*, petal trace; *pm*, petal midrib; *sl*, sepal laterals; *sm*, sepal median; *sta*, staminal filament; *sg*, stigma). Figs. 15–27. Serial transections from pedicel upwards.

the base which at higher regions becomes a siphonostele (Fig. 28). This feature was not observed in other species.

Above the level of staminal traces the disc which receives no vascular supply is seen as a deeply stained parenchymatous tissue.

The vasculature of the carpels consists of dorsals, secondary marginals and ventral traces. The secondary marginals arise independently in *Zygophyllum* (Figs. 59, 60), or commissurally in *Peganum* and *Nitraria* or fused with dorsal traces in *Tribulus* and *Fagonia* (Figs. 8, 9, 34, 35). Both dorsals and secondary marginals show a certain amount of anastomosis in the ovary wall. The ventral bundes in species of *Tribulus* and *Fagonia* remain close together along the dorsal

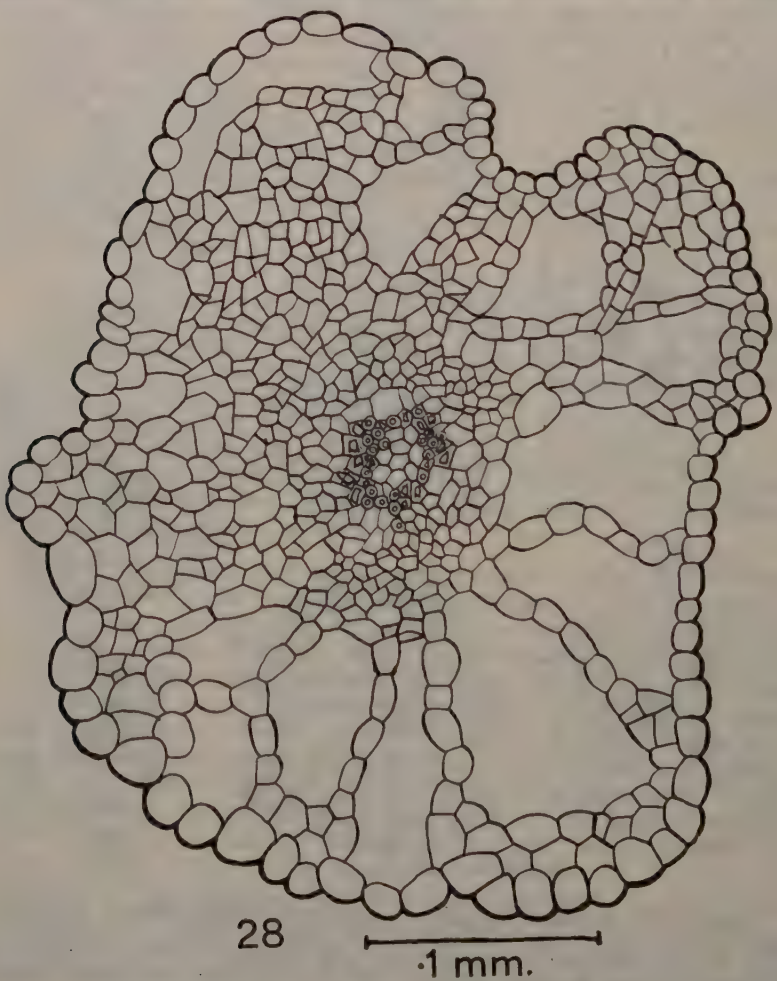
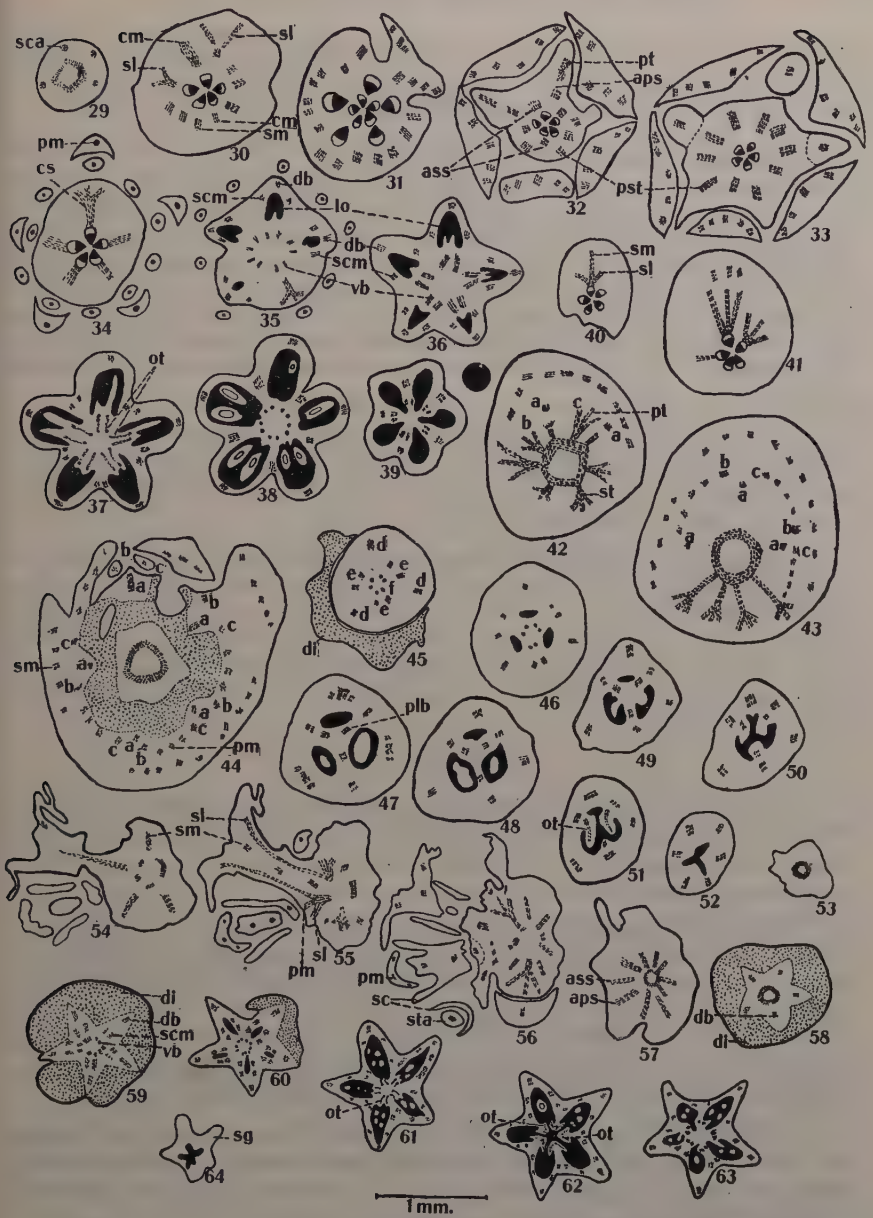


FIG. 28. *Peganum harmala*. T.S. filament of stamen.



FIGS. 29–63. (*a*, supply to median stamen; *aps*, antipetalous staminal supply; *ass*, antisepalous staminal supply; *b*, *c*, supply to lateral stamens; *cm*, commissural trace of sepals; *cs*, carpellary supply; *d*, dorsal trace; *db*, dorsal bundle; *di*, disc; *e*, secondary marginal trace; *f*, ventral trace; *lo*, locule; *ot*, ovular trace; *plb*, placental bundle; *pm*, petal midrib; *pst*, petal stamen trace; *pt*, petal supply; *sc*, staminal scale; *sca*, sclerenchymatous patches; *scm*, secondary

marginal bundle; *sg*, stigma; *sl*, sepal lateral; *sm*, sepal midrib; *sta*, stamen; *vb*, ventral bundle). Figs. 29–39. *Fagonia arabica*. Serial transections from pedicel upwards. Figs. 40–52. *Nitraria retusa*. Serial transections from pedicel upwards. Figs. 53–64. *Zygophyllum dumosum*. Serial transections from pedicel upwards.

radii without fusing with each other (Figs. 9–11, 35–37). In *Peganum harmala* and *Nitraria retusa* the ventrals are in the septal radii. While the ventrals of adjacent carpels remain separate in *P. harmala* (Figs. 22–25) they fuse with one another in *Nitraria retusa* (Figs. 47–51). *Zygophyllum* species differ from the above members in having ventral bundles at first along the dorsal radii; these ventral bundles after supplying the lowermost ovules now swing along the septum and supply the rest of the ovules (Figs. 61, 62). At this level the placentas recede to the periphery. The placental bundles are inversely oriented in all species studied.

Each carpel bears large number of ovules in *Peganum* and *Zygophyllum*, four or five in two rows in *Tribulus*, two collateral in *Fagonia*, and a single ovule in *Nitraria*. The ovulesiss are bitegmic and anatropous. An ovule is supplied by a single trace.

Variation is noticed in the vascular supply to the style. Extensions of all the bundles of the carpels enter the style in *Tribulus*, *Zygophyllum* and *Nitraria* where some of them fuse and ultimately fade at the stigmatic region. In *Peganum* and *Fagonia* the ventrals alone furnish the stylar supply. In *Peganum* the bundles divide at the higher regions of the long slender style and each stigmatic lobe receives 5–6 bundles (Figs. 26, 27).

Discussion

The vascular anatomy of the species studied follows a basic pattern. The variation met with can be regarded to be the result of either reduction or fusion between members and their vascular supply of the same whorl and between adjacent whorls.

The data presented above suggests that the sepal was originally a three trace organ and in *Nitraria retusa* the traces to each sepal came closer and ultimately fused to form single strand but dividing into its components at the base of the sepal. In *Fagonia mollis* and *F. arabica*, on the other hand, the laterals of adjacent sepals got fused. *Tribulus terrestris*, *T. alatus* and *Peganum harmala* are yet a step forward by the formation of commissural strands fused with petal traces.

Saunders (1937) stated that in species of *Zygophyllum* and *Tribulus* the antisepalous and antipetalous staminal traces are conjoint with sepal and petal midribs respectively. The present study does not support her findings.

Obdiplostemony is present in all the members studied. It is also seen in the allied families Geraniaceæ, Rutaceæ, Simaroubaceæ, etc. This phenomenon may be brought about in a number of ways (see Puri, 1951). Saunders (1937) offers an interpretation for obdiplostemony in Zygophyllaceæ. She writes " The antipetalous stamen bundles

arise conjoint with sepal marginals and petal midribs and in this way are carried out some distance from the central cylinder before they become independent. In some species the antisepalous stamen bundles are similarly carried out united with sepal midrib bundles, but for a shorter distance, so that when detached they stand nearer the centre than the detached bundles of the antipetalous stamens. In these species obdiplostemony results....". The independent origin of staminal traces in some of the members studied here does not support the explanations given by Saunders for obdiplostemony in the family.

The conspicuous parenchymatous intrastaminal disc receives no vasculature. The present study does not help in the determination of the exact morphological nature of the disc.

The placentation in the family is considered axile by Rendle (1952), Gundersen (1950) and Lawrence (1951). According to Puri's (1952) definitions the placentation in *Tribulus* and *Fagonia* is axile and anatomically parietal in *Peganum harmala* and *Nitraria retusa*. The inverse orientation of the placental bundles in these species may be accounted in the manner envisaged by Puri (1952). *Zygophyllum* species is interesting in showing an axile placentation below and parietal above and so we regard the placentation in these species is on its way towards the parietal type.

The systematic position of *Peganum* is controversial. Hooker (1875) includes this genus under Rutaceæ while it is considered a member of Zygophyllaceæ by Engler and Prantl (1931), Warming and Potter (1932), Metcalf and Chalk (1950), Willis (1951), Lawrence (1951), and Erdtman (1952). The present work shows that the floral structure and anatomy of *Peganum harmala* is closely similar to other members studied, particularly *Nitraria retusa*, thus supporting its retention in Zygophyllaceæ.

According to Saunders (1937) the organography and vascular anatomy of *Peganum* is closely similar to *Monsonia* and *Sarcocaulon* of Geraniaceæ and *Hypsocharis* of Oxalidaceæ. These similarities suggest only a parallel development than relationship.

Summary

The present work deals with the floral anatomy of eight species of Zygophyllaceæ: *Tribulus terrestris*, *T. alatus*, *Zygophyllum dumosum*, *Z. simplex*, *Fagonia arabica*, *F. mollis*, *Peganum harmala*, and *Nitraria retusa*. The flowers are pentamerous and pentacyclic.

The sepal trace in *Nitraria* divides into three in the receptacular cortex. In *Zygophyllum*, *Tribulus* and *Peganum* the sepal laterals are fused with petal traces and in *Fagonia* the calyx is supplied by midrib and commissural traces. Each petal receives a single trace.

The stamen in *Zygophyllum* has a bilobed scale at the base and in *Tribulus* the antisepalous stamens are provided with bilobed glands. These structures appear stipular in origin.

Anatomical evidence for obdiplostemony in the family is presented. In *Nitraria* and *Peganum* the outer whorl of stamens are duplicated. The staminal filament in *Peganum* shows a siphonostele.

A conspicuous nonvascularised parenchymatous intrastaminal disc is present.

Each carpel receives a dorsal trace two secondary marginals and two ventral traces. While the placentation in *Tribulus* and *Fagonia* is axile, it is parietal in *Peganum* and *Nitraria*. *Zygophyllum* species have an axile placentation at the base and parietal above.

In conclusion we are thankful to Dr. A. Fahn, Hebrew University, Jerusalem, for sending us materials from his valuable collections, to Dr. K. Subrahmanyam, Regional Botanist, Southern Zone, for kindly going through the manuscript and suggesting several improvements and to Dr. B. N. Mulay for suggestions, facilities and encouragement.

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MORPHOLOGY AND VASCULAR ANATOMY OF THE SPIKE OF *MNESITHEA LÆVIS* (Retz.) Kunth.*

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(Received for publication on November 19, 1957)

Introduction

Arber (1934) has made an important contribution to our knowledge of floral morphology of the Gramineæ in general. But, no detailed work of that nature has so far been done on Indian grasses. Consequently a scheme financed by C.S.I.R., New Delhi, has been undertaken to make a systematic study of floral morphology of the grasses which occur locally and elsewhere in the country. During the course of such a study which is in progress in this laboratory the author came across certain interesting grasses belonging to the subtribe Rottbœllinæ (Tribe Andropogoneæ) which provided interesting structural and anatomical data. Uptill now a number of species belonging to this subtribe and other tribes have been studied anatomically. But of all these *Mnesithea lævis* (Retz.) Kunth. (Syn. *Rottbœllia perforata* Roxb.) appears to be most interesting in so far as it reveals certain significant features concerning the morphology of the grass spikelet and its flower. Consequently, in this communication attention will be confined to this species.

Material and Methods

The material of *Mnesithea lævis* was collected in August, 1956 from Hastinapur, about 30 miles north of Meerut. The grass occupied large tracts of land in a forest area. Young and old spikes were fixed in F.A.A. The older spikes being hard required pretreatment with 5% solution of KOH for three or four days before dehydration. Thereafter, the material was washed, dehydrated, passed through different grades of xylol and then embedded in paraffin in the usual way. The material required 3–4 days in a paraffin bath for perfect penetration with paraffin. Serial transverse sections, 12–14μ thick were cut and stained with crystal violet and erythrosin which gave satisfactory results.

Observations

External Morphology.—M. lævis (Retz.) Kunth. is an erect, slender perennial grass with smooth, simple or branched stems varying in height from 2–4 feet.

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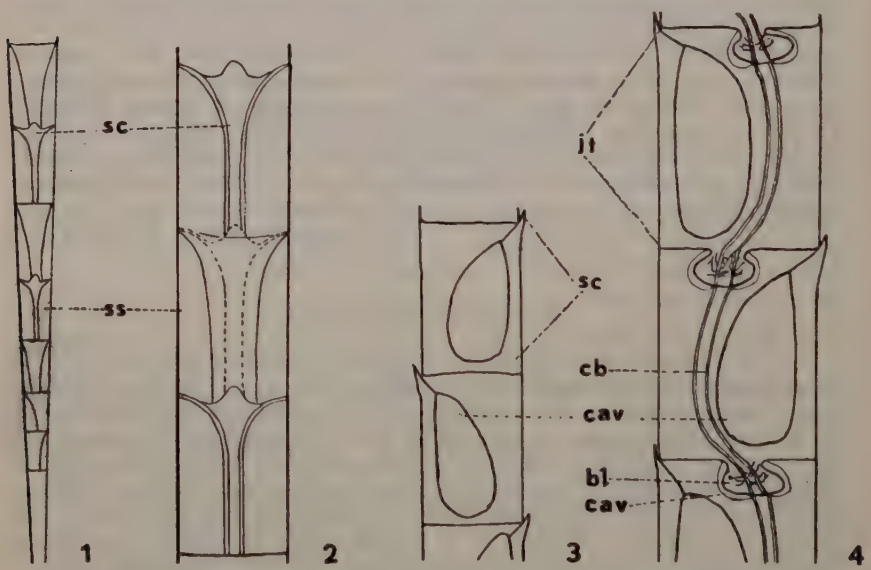
* Contribution No. 12 from the School of Plant Morphology, Meerut College, Meerut.

The spikes which are 4–10 inches long are exerted from the uppermost sheaths and are erect. They are jointed (Fig. 1), some lower and a few upper joints being smaller. At maturity a spike breaks up into individual joints each of which consists of a portion of the axis with two sessile spikelets and an interposed 'scale-like' structure. The condition in a few lowermost and some uppermost joints of the spike, however, is different. In the uppermost joints there is always present a single sessile spikelet in each joint while in the lowermost one or two joints there is either a single (Fig. 1), or a pair of sessile spikelets. The sessile spikelets which are present at the base of each joint are placed in oblong cavities formed as a result of excavation of the axis. These cavities are almost as long as the joint itself (Figs. 3 and 4), and they are partially separated from each other by the inwardly projecting portions of the axis and the 'scale-like' structure (Fig. 24). The pair of sessile spikelets of a joint is opposite to one down below or above. Thus alternate pairs are superimposed in regular order (Figs. 1 and 2). The 'scale-like' structure separates from the joint at the base and is free all along the length of the joint but for a short connection upward beyond which it separates off as a minute appendage (Figs. 3 and 4).



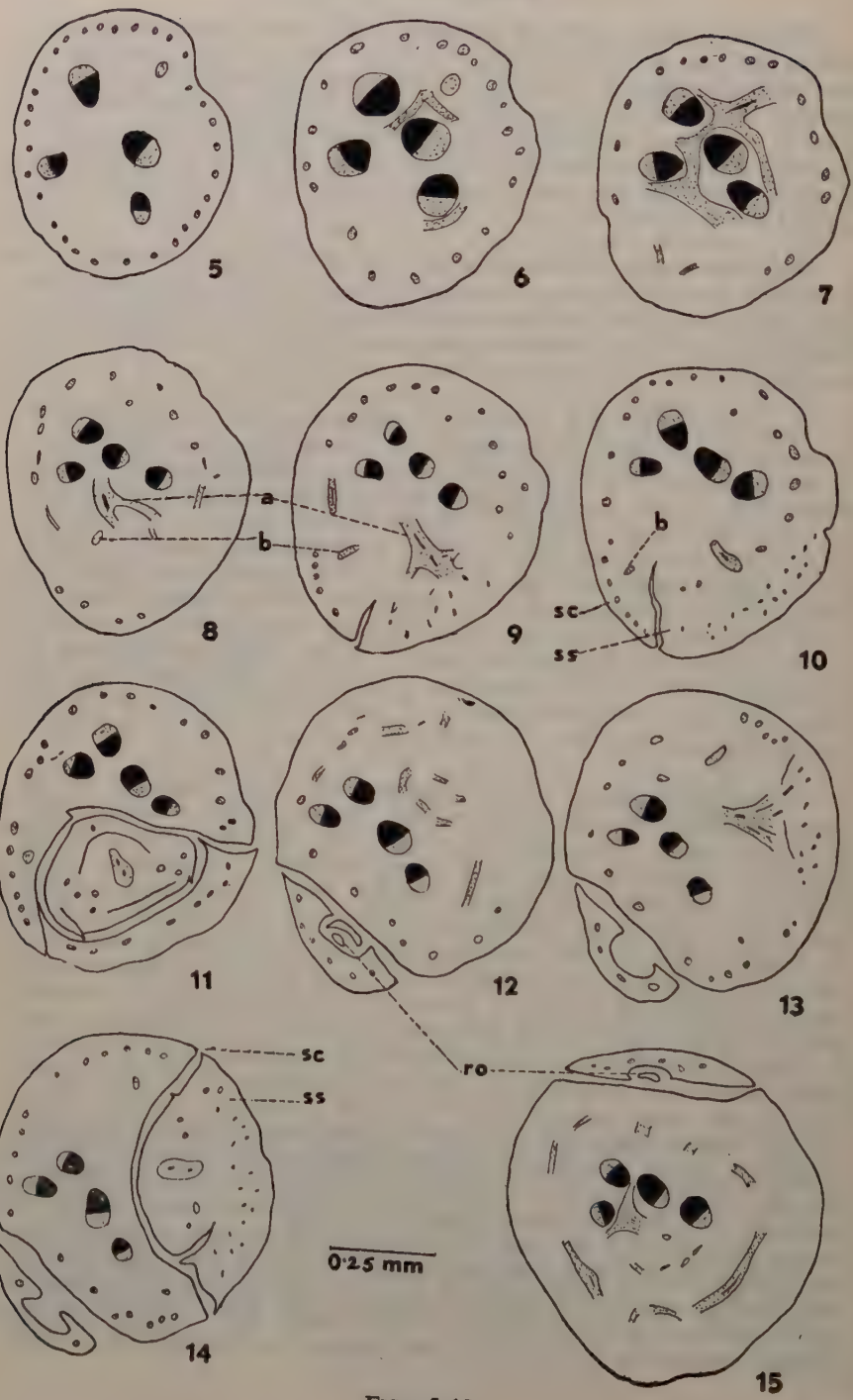
Figs. 1–4. Fig. 1. Diagrammatic representation of lower portion of spike of *M. lævis* showing the lowest two joints having one sessile spikelet each and the rest having paired sessile spikelets. Fig. 2. Middle portion of the spike with 3 consecutive joints enlarged. Note two sessile spikelets at each joint and the interposed 'scale-like' structure. Figs. 3 and 4. Sectional view along the long axis of the spike cut at right angle to the sessile spikelets. Note the ball-like structure of the upper joint fitting into the concavity of the lower joint and the central vascular bundles entering into it and forming a plexus. (*bl*, ball like structure; *cav*, cavity; *cb*, Central vascular bundles; *jt*, joint; *sc*, 'scale-like' structure; *ss*, sessile spikelet.)

On closer examination a separated joint reveals a ball-like structure at the base and a concavity at the top (Fig. 4). In young condition when the spike is intact, the 'ball' of the upper joint fits into the cavity of the lower one and receives the stele of the four central bundles (Fig. 4). The two consecutive joints are also held up together as they are also connected at the nodal region (Fig. 4). It is as a result of abscission at these two places that the separation of the joints take place.

Vascular Anatomy of the Spike.—In the stalk of the spike there are four large bundles which are centrally placed (Fig. 5). They are conjoint and closed and are surrounded by a ring of small, peripheral bundles which consist mostly of phloem with only one or two poorly developed xylem elements (Fig. 5).

Just below the first joint of the spike the four central bundles anastomose and form a plexus (Figs. 6 and 7). Occasionally, one of the peripheral bundles also joins the central bundles during anastomosis (Figs. 6 and 7). Meanwhile, the peripheral bundles of the side on which the sessile spikelet is present migrate towards opposite side (Figs. 7 and 8) and two traces '*a*' and '*b*' diverge out from the central plexus in this direction (Figs. 8 and 9). Out of these two traces '*a*' which is quite prominent goes to supply the unpaired sessile spikelet, while '*b*' passes on in its adjacent region and along with 4–7 peripheral bundles constitutes the vascular supply of the 'scale-like' structure in which bundle '*b*' can be recognised towards the inner side (Fig. 10). This 'scale-like' structure separates off from the axis at the base of the next higher joint and bears a rudimentary spikelet (Figs. 12 and 15).

After supplying the various organs of the lower joint the central plexus again splits up into four bundles. A little higher up where there are paired sessile spikelets at each node the four central bundles are arranged in two pairs of two each on the two sides of the central cavity (Fig. 16). All these four central bundles enter the ball-like structure and form a plexus of vascular tissue (Figs. 17–19). This 'ball' with its vascular plexus is free from the peripheral portion of the axis which contains a ring of small peripheral bundles (Fig. 18). It may be mentioned here that this peripheral portion of the axis belongs to the lower joint while the 'ball' is the downward projection of the upper joint. At every node in this region of paired sessile spikelets, most of the peripheral bundles of the side on which sessile spikelets are present migrate towards the other side (Figs. 20 and 21). Whatever vascular tissue remains behind breaks up at a slightly higher level into 4–7 peripherals, which are present in between the two sessile spikelets and which constitute the vascular supply of the 'scale-like' structure (Fig. 23). Besides, the latter also receives a small bundle '*b*' from the central plexus of vascular tissue (Figs. 21 and 22). This bundle occupies a position towards the inner side (Fig. 24) and on either side of it, there differentiates and diverges out a stouter strand ('a_1' or 'a_2') for either of the two sessile spikelets (Figs. 21 and 22). The central four bundles now reorganise themselves and occur in two pairs of two each (Figs. 23 and



FIGS. 5–15

FIGS. 5–15. A series of transverse sections passing through portions of two consecutive lowest joints each with a single sessile spikelet. Also note the concrescent scale-like structure (*sc*) having rudimentary organs (*ro*) at the top. (Abbreviations same as in previous figures.)

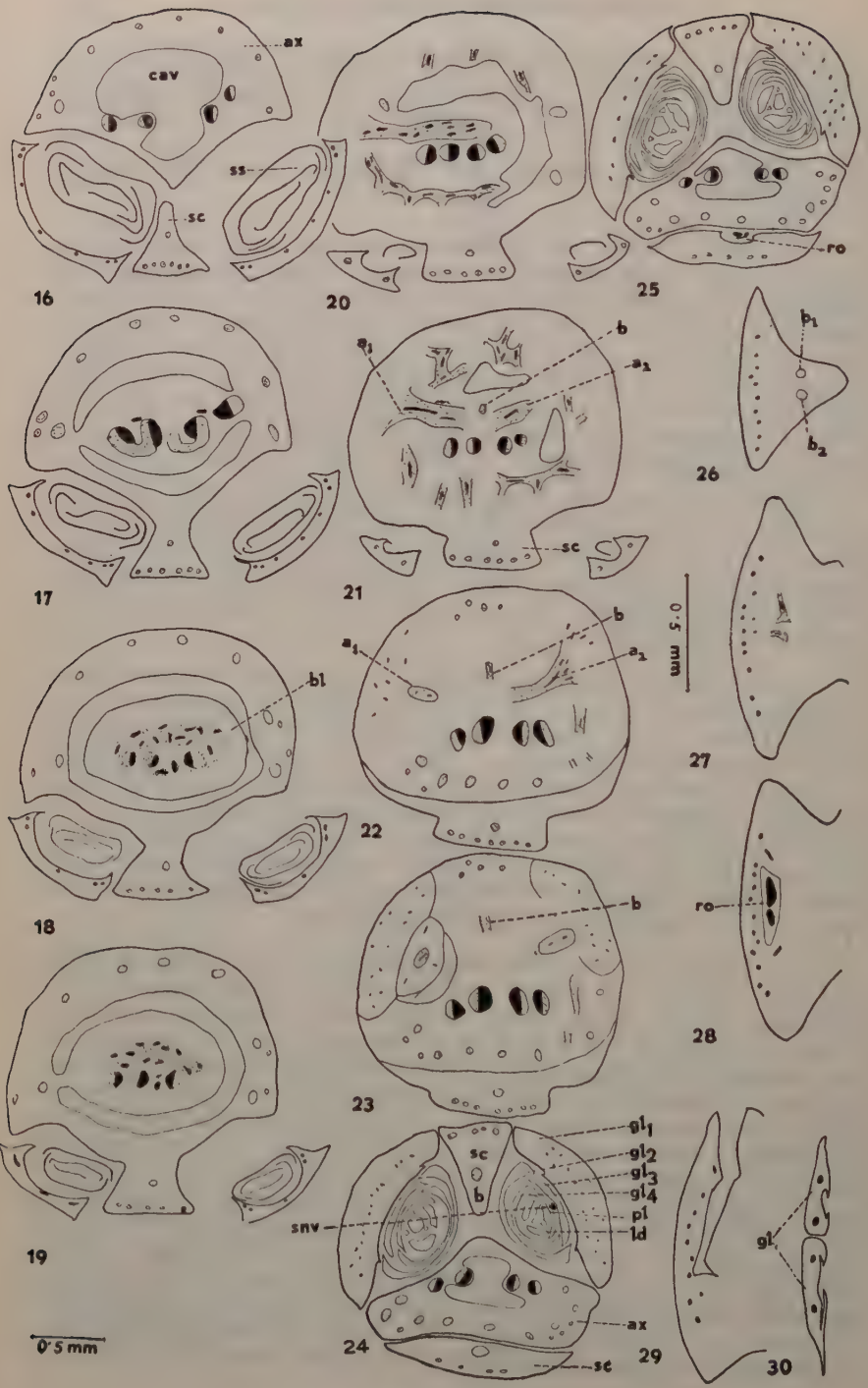
24). Xylem of both these pairs of bundles is oriented towards the centre of the axis.

The sessile spikelet and its vascular anatomy.—The sessile spikelet has two outer empty glumes, the outermost, which is away from the main axis of the spike, is thick and coriaceous and has narrowly inflexed margins (Fig. 44, gl_1). The second empty glume which is on the opposite side is equal in size to the first glume, but is thinner in texture (Fig. 44, gl_2). This is followed in regular sequence by a third glume which also does not bear any flower and is hyaline (Fig. 44, gl_3). The fourth glume opposite the third is fertile and paleate and bears a normal flower having two lodicules, three stamens and a gynœcium (Fig. 43).

In one case there were five glumes instead of four (Fig. 51). Four of these did not bear any flowers while the fifth one was fertile and had a flower in its axil (Fig. 51). This flower, as is to be expected, occupies a place opposite to the one normally occupied by the floret of the fourth glume. Such a situation will obviously be useful in determining the nature of the glumes.

A noteworthy feature of the first, second, third and fourth glumes is the presence of a layer of specialized cells on the inner surface (Figs. 31–34). In the first glume all the cells of the inner epidermis are very large and thin-walled. These cells, however, are confined to the distal portion of the glumes. They are very poor in cytoplasmic contents. In glumes second, third and fourth also such a cell layer is present, but the cells are not so prominent as they are in glume I. Such cell layers are not present at the same levels in different glumes. It seems probable that these cells by changes in turgor might help in the opening of the spikelet, thus facilitating anthesis.

It will be recalled that each sessile spikelet receives a mass of vascular tissue 'a_1' or 'a_2', which gives out 15–20 minute traces for the outermost empty glume wherein they are irregularly distributed (Figs. 22, 23 and 35). At a higher level they unite into 8–10 bundles that are arranged in a single file parallel to the inner face of the glume (Fig. 44). Further up they decrease in number until only two bundles are left in the apical region (Figs. 16–21). Thereafter, the main stele gives off two traces (*x* and *y*), one on either lateral side (Fig. 35) and one minute trace '*m*' on the anterior side (Fig. 36). The bundles '*x*' and '*y*' supply lateral nerves to second, third and fourth glumes and the palea. These give off one minute branch each, x_1 and y_1 (Fig. 36), which along with the trace '*m*' constitute the vascular supply of the second glume (Figs. 36–39). The remaining portions of '*x*' and '*y*' resolve now into three minute traces each (x_2, x_3 and x_4; y_2, y_3 and y_4) (Fig. 40). 'x_2' and 'y_2' of these enter the base of the third glume which thus receives only two marginal nerves and no median bundle (Figs. 41 and


ax
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16
20
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21
b
a1
a2
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26
b1
b2
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0·5 mm
27
23
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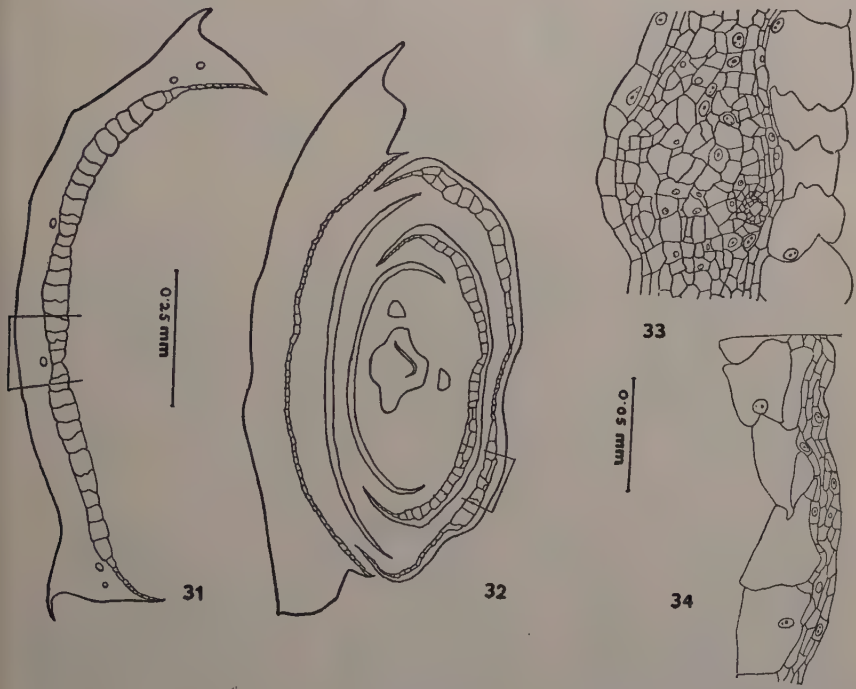
28
19
24
snv
sc
b
gl1
gl2
gl3
gl4
pl
ld
ax
sc
29
30
gl
0·5 mm

FIGS. 16–30

FIGS. 16–30. Figs. 16–25. A series of transverse sections of a joint from below upwards showing the origin of vascular supply to the sessile spikelets and the 'scale-like' structure; Figs. 26–30. A series of transverse sections from below upwards of the abnormal 'scale-like' structure showing double vascular supply and having at the top some rudimentary organs and 2 glumes, each with two marginal bundles (*ax*, axis of the spike; gl_1 to gl_4, glumes 1–4; *ld*, lodicule; *pl*, palea; *ro*, rudimentary organs; *snv*, solid non-vascular structure).

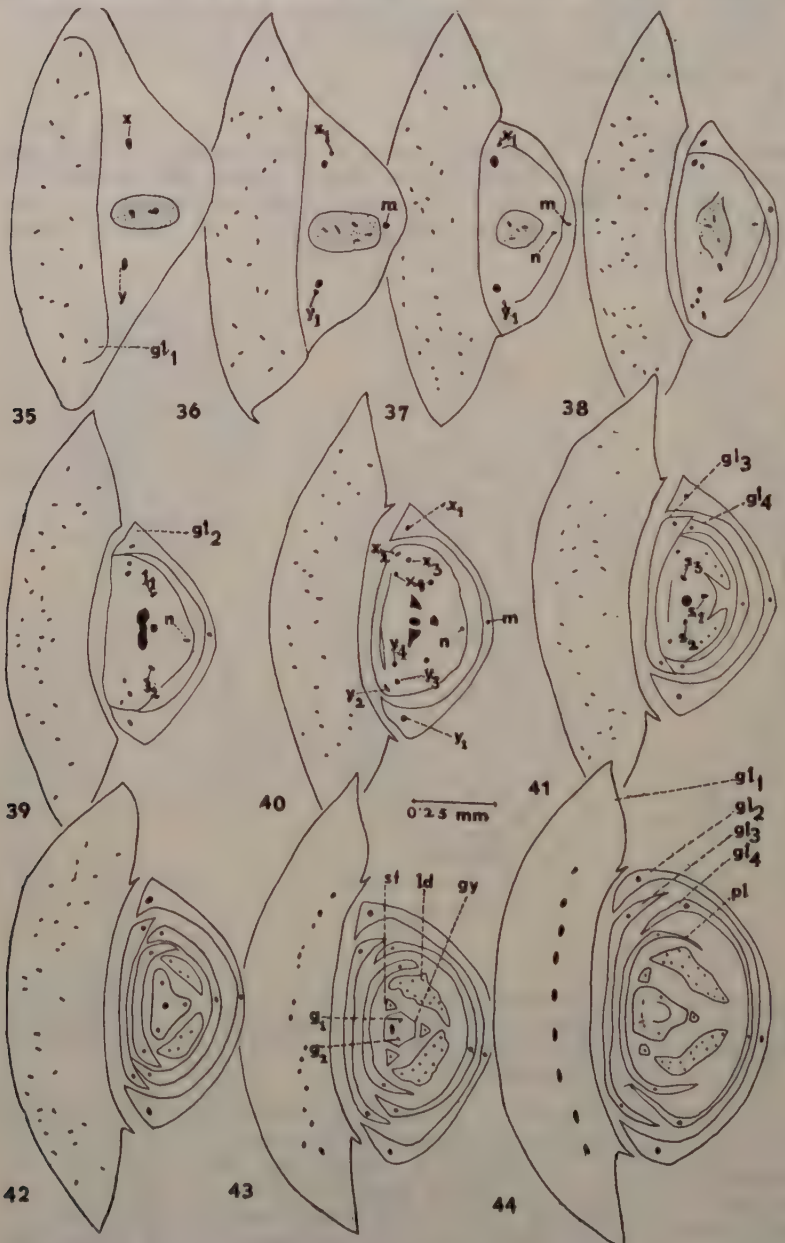
44). The next pair 'x_3' and 'y_3' now enters the base of the fourth fertile glume (Fig. 41). A minute trace '*n*' also diverges out from the main stele on the anterior side for the fourth glume and becomes its median nerve (Figs. 40 and 41). The remaining two laterals 'x_4' and 'y_4' enter the palea of the fourth glume which is thus binerved (Figs. 41 and 42).



FIGS. 31–34. Fig. 31. Transverse section of glume 1 of a sessile spikelet showing the inner epidermal cells enlarging in upper region; Fig. 32. T.S. of a sessile spikelet showing the same in other glumes; Figs. 33 and 34. Portions marked in Figs. 31 and 32 respectively magnified.

Meanwhile, two traces 'I_1' and 'I_2' diverge out from the main stele one on either side in the anterio-lateral direction and each enters a lodicule (Fig. 39). Soon after it divides into three (Fig. 41), and subsequently into 9 or 10 smaller branches which are arranged in a bifacial manner forming a sort of flattened cylinder in T.S. (Fig. 43). After the departure of lodicular traces, three staminal traces diverge out from the main stele (Figs. 40 and 41), one (S_1) on the anterior side and

two (S_2 and S_3) on the lateral sides. These enter the bases of the respective filaments and traverse the whole length of the stamen. The



FIGS. 35–44. Series of transverse sections of a sessile spikelet from below upwards showing vascular supply to different organs.

remaining stelar tissue gives off two minute traces ('g_1' and 'g_2') one on either side (Figs. 45–50). They traverse the whole length of the ovary wall and pass into the two plumose stigmas. Just after the divergence of these traces the residual stelar tissue breaks up into three or four minute branches which arrange themselves in an arc in T.S. (Figs. 47–49). All these are consumed in supplying the solitary ovule.

During the course of this study some interesting abnormalities have been brought to light. It will be worthwhile to refer to them briefly here. Most of these, however, were found associated in a single spikelet.

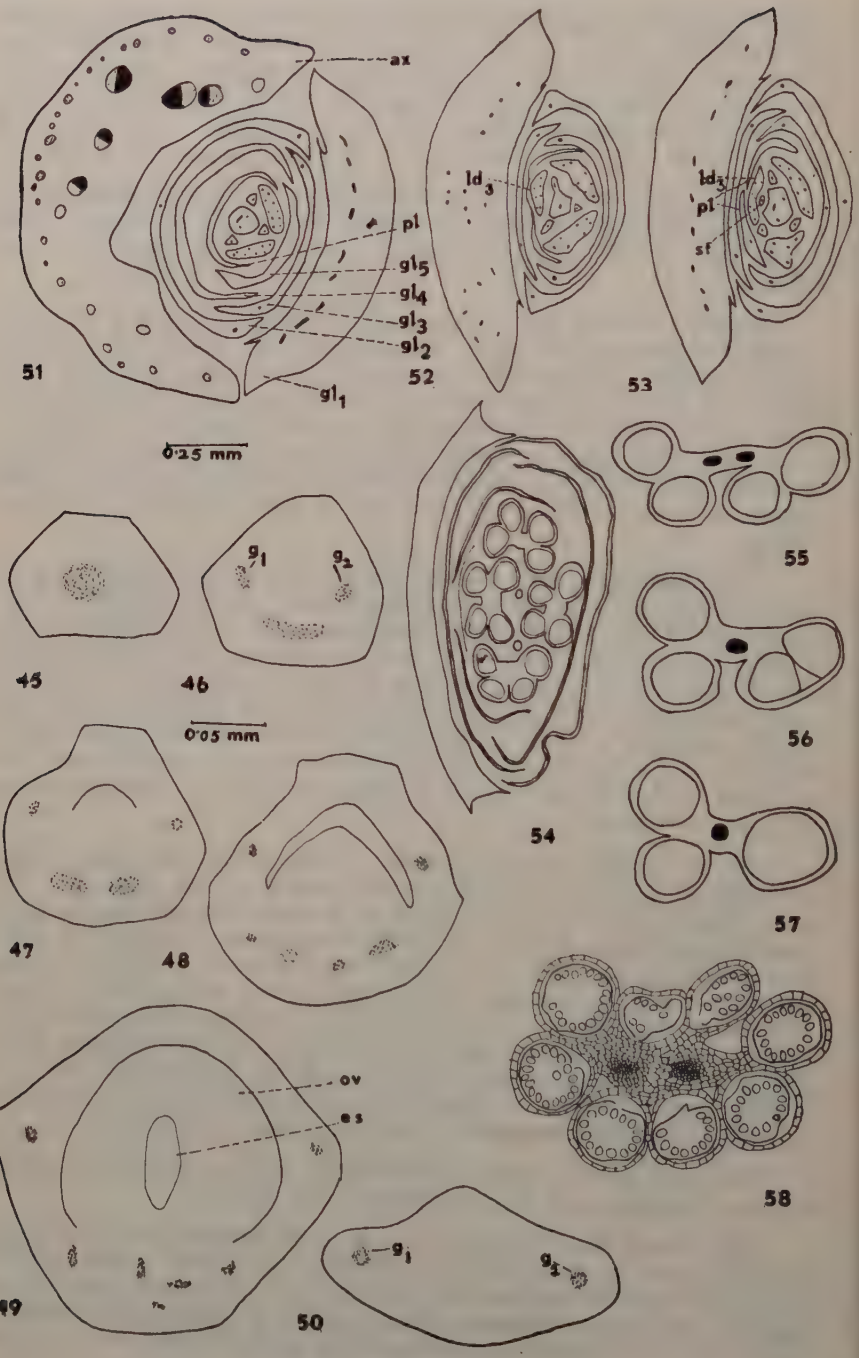
In a few cases it was found that the palea divided into two lobes in the apical region (Fig. 53). This abnormality was found associated with a number of other abnormalities. For instance in a few cases there were three lodicules instead of the usual two (Figs. 52 and 53, ld_3). In structure the third lodicule was just similar to the other two. It had its usual vascular supply (Figs. 52 and 53). It occurred on the posterior side rendering the arrangement of lodicules similar to that found in bamboos where the presence of three lodicules is a normal feature.

The androecium also showed certain abnormal features. In one instance there was an increase in the number of stamens from 3 to 4 (Figs. 53 and 54). The fourth stamen which was quite normal occupied a posterior position between the palea and the ovary. In another case, one of the lateral stamens showed a double structure as there were eight pollen sacs instead of four (Fig. 58). The filament in the basal region contained a single vascular strand which divided higher up into two (Fig. 58). Further up the four pollen sacs of one side separated off from the four of the other side, each group with a connective having a minute vascular strand.

In yet another case one of the stamens which was quite normal in structure had two vascular strands instead of one (Fig. 55). This was probably the result of division of a single vascular bundle in the lower region of the filament. In two instances there were three pollen sacs in one stamen at certain regions of the anther. In one of them there were four pollen sacs in the basal region while higher up only three were there (Figs. 56 and 57). This reduction in the number of pollen sacs was brought about by the fusion of two adjacent pollen sacs which resulted by the dissolution of the intermediate wall. In another case there were four normal pollen sacs below and higher up whereas in the middle region of the anther there were only three.

In a few instances there was observed a solid non-vascular structure between the palea and the third glume (Fig. 24, *snv*).

The 'Scale-like' Structure.—It may be recalled that the 'scale-like' structure is interposed between the two sessile spikelets and is connected with the axis at the base and in the upper region. At its extreme tip it again becomes free and bears some organs (Figs. 4, 16–25, *sc*). In the middle portion of the joint it is free from the axis.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ld3
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56
57
45
46
g1
g2
0·05 mm
47
48
ov
es
49
50
g1
g2
58

FIGS. 45–58

FIGS. 45–58. Figs. 45–50. Series of transverse sections of a gynæcium from base upwards. Fig. 51. Abnormal sessile spikelet having 5 glumes instead of 4—the 5th being paleate and fertile bearing the flower with reversed orientation; Figs. 52–54. Transverse sections of abnormal sessile spikelets showing 3 lodicules. Note the posterior position occupied by the 3rd lodicule. Also note 4 stamens in Figs. 53 and 54 and divided palea in Figs. 53 and 54. Figs. 55–58. Abnormal stamens. Note 2 vascular strands in Fig. 55 and 2 vascular strands and 8 pollen sacs in Fig. 58. Figs. 56 and 57 represent sections from lower and upper portions respectively of the same anther having 4 and 3 pollen sacs at different levels ($l\,d_3$–3rd lodicule; *st*, stamen; *ov*, ovule; *es*, embryo-sac).

In a few lower and some uppermost joints where only one sessile spikelet is present the ' scale-like ' structure is adnate to the axis throughout its length except for its terminal portion which ends in some rudimentary organs. As has been stated earlier the scale-like structure gets 4–7 peripherals and one bundle '*b*' derived from the central plexus (Figs. 21 and 24). In one case, however, it was seen that there were two bundles 'b_1' and 'b_2' instead of the normal one (*b*) and the peripherals also became 10–12 instead of 4–7 (Figs. 26–30). The bundles 'b_1' and 'b_2' independently gave out traces towards the sides for the rudimentary organs and were consumed. The peripheral portion with its vascular bundles which should have normally developed into a glume divided through the middle into two structures (Figs. 30). Each of these latter had inflexed margins and only two bundles one at each margin. It will be recalled that both these features characterize the outermost empty glume of a sessile spikelet.

DISCUSSION

The Sessile Spikelet.—The observations recorded here seem to throw some light on the trends of specialization and evolution in the sessile spikelet. It may be recalled that each sessile spikelet in *Mnesithea lævis* has four glumes, the lower three of which are sterile while the fourth one is paleate and bears a single flower. There is little doubt that the first and second glumes are the empty glumes as is the case in the majority of grasses. Regarding the third glume which is also sterile, it appears that it is the lemma of the first floret that is completely suppressed. The position of this third glume after the two empty glumes is one reason for such a belief. Besides, there is a general tendency to imperfection of the lower (*Ist.*) floret in the whole of the subfamily Panicoideæ. In the subtribe Rottbœllinæ itself there are many cases in which either the lower floret is male or bears rudimentary organs only. In *Ophiurus exaltatus* I have seen that the lower floret bears only rudimentary organs except for the lodicules which are well developed. Therefore, we can say that this tendency for imperfection of the lower floret has probably resulted in complete suppression of the lower flower as also the palea while only the lemma persisted. Further, as has been mentioned above there is occasionally found a solid non-vascular structure in between the third glume and the palea of the fourth glume. This may either be a remnant of the lower floret or merely a rachilla. In *Sorghum sudanense* and *Sorghum halepense* the third glume is sterile and presents the same position as is found in *Mnesithea lævis*. Long (1930) found regions of embryonic

tissue in a plane above the third glume and the palea of the fourth glume in these grasses. On this and some other evidences he has come to the conclusion that the third glume is the lemma of the suppressed lower floret.

In one case, however, I found five glumes instead of the normal four. Four of these did not bear any florets while the fifth had a normal flower and as should be expected it was reversely oriented with respect to the flower of the fourth glume. So the single flowered sessile spikelet of *Mnesithea lævis* appears to have been derived through reduction and suppression from an ancestral sessile spikelet having at least three florets one each in the axil of third, fourth and fifth glume.

Lodicules are quite well developed in this species and it is surprising to find how so careful observers as Bor (1940) and Rangachariyar and Mudaliyar (1921) missed them. The occasional presence of the third lodicule on the posterior side is of special significance as it is generally absent in the grasses except for certain bamboos where it is a normal feature. The presence of this third lodicule may be regarded as a retention of a primitive feature. It also supports the trimerous nature of the gramineous flower.

The 'Scale-like' Structure.—In the tribe Andropogoneæ there is generally present one sessile and one pedicelled spikelet at each joint. In the subtribe Rottbœllinæ the condition is complexed as the sessile spikelets are sunken in the excavated axis and the stalk of the pedicelled spikelet is concrescent with the axis. In *Mnesithea lævis* the condition is all the more complicated by the presence at each node, of two sessile spikelets instead of the normal one and there being no evident pedicelled spikelet although there is present a 'scale-like' structure interposed between the two sessile spikelets. In a few lowest and some uppermost joints however, there is only one sessile spikelet and an adnate 'scale-like' structure which bears some rudimentary organs at the top. In these joints the position occupied by the 'scale-like' structure with respect to the axis and the single sessile spikelet is the same as the position occupied by the pedicelled spikelet with respect to the axis and the sessile spikelet in certain allied genera, *e.g.*, *Hemarthria* and *Rottbœllia*. Besides, the 'scale-like' structure always bears, at its apex, a leafy structure and some other rudimentary organs. The leafy structure resembles very much the outermost empty glume of the sessile spikelet inasmuch as it has inflexed margins and two bundles in the apical region.

Taking all these points into consideration there is little doubt that the 'scale-like' structure represents the pedicelled spikelet. Hooker (1897), Bor (1940), etc., also describe this structure as the pedicel of the third imperfect spikelet, two perfect ones being sessile.

Attention may be drawn here to an abnormal case where the 'scale-like' structure has double vascular supply. At the apex it splits up into two leafy structures with recurved margins which subtend some rudimentary organs in their axils. If these leafy structures are to be

interpreted as the outermost glumes of two distinct pedicelled spikelets (and this seems to be the only logical interpretation) then the 'scale-like' structure will have to be interpreted as a 'double' structure formed by the fusion of two pedicelled spikelets corresponding to two sessile spikelets.

Arber (1934) also has described abortive pedicelled spikelets in *Ischæmum rugosum* Salisb., a member of the Andropogoneæ, and she has correlated the pedicellate character of the spikelet with sterility. Apparently a similar correlation exists in *M. lævis* also.

Summary

1. The structure and vascular supply of the spike and the spikelets of *M. lævis* (Retz.) Kunth. have been described.

2. Each sessile spikelet generally has four glumes; the lowest two of these are interpreted as the empty glumes. The third is considered as the lemma of the first flower that has been completely suppressed and the fourth is the lemma of the second flower which is functional.

3. The glumes of the sessile spikelet have prominently large epidermal cells on their inner faces probably to help in anthesis.

4. The occasional presence of a third posterior lodicule supports the trimerous nature of the gramineous flower.

5. The structure of the 'scale-like' organ has been described and it is concluded that it represents one or two pedicelled spikelets in a state of complete imperfection.

Acknowledgements

I am extremely grateful to Prof. V. Puri, Officer-in-charge of the scheme, for guidance and for permission to publish these results and to Dr. Y. S. Murty for some helpful suggestions. I am also thankful to Shri M. B. Raizada of the Forest Research Institute, Dehra Dun, for identification of the species. Thanks are also expressed to the authorities of the Council of Scientific and Industrial Research, New Delhi, for a grant of Junior Research Assistantship during the tenure of which this work was done.

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EFFECT OF TRANSPLANTATION ON RAGI PLANT

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Received for publication on May 6, 1957

Introduction

Much work has been done on the study of root systems of various plants in relation to soil, soil water and other allied factors by workers like Weaver, Bruner, Clements, Loomies and Miller. Turner (1908) stated that when the plants are transplanted by trench method, the roots invariably develop in the plane corresponding to the longitudinal axis of the trench. Weaver and Bruner (1927) arrived at the conclusion that as a result of transplantation many new roots developed and they formed a compact mass near the stem and the main advantage of transplantation is the much branching of roots, the general overall effect being retardation of development. The degree of retardation in growth varies with the kind of plant, its age and the conditions under which it is transplanted. With advancing maturity, injury from transplantation increases in all crops. A single transplantation at a later age is more harmful than two or three in the early age and transplantation reduces yields, more so, if the spacing is same as in the control. According to Jones (1922) transplanting affected early production, whereas the non-transplanted plants had a better root system, grew much faster and came to bearing earlier.

Ramiah (1937) working on rice showed that double planting in fertile soils, yields more grain and less straw but in poor soils it was the reverse; and single planting of vigorous seedlings is much better than double planting.

Singh (1953) stated that in chillies the second transplanted plants had a good vegetative growth, grew much taller, flowered a month earlier, yielded more (50%) and lived longer than the first and the third transplanted plants.

The present work on millets was undertaken to study the influence of transplantation on general growth of both root and shoot systems and the yield of grain and straw.

Materials and Methods

Eleusine corcana Gærtn. strain A.K.P. 2 was used throughout the experiments. The seed material was obtained from the Millet Specialist, Lam Farm, Guntur District.

One cent plots were laid out for experiments and usual farm practices followed; selected seeds were sown in lines one inch deep, covered, pressed and watered. The seedlings were first transplanted in

the third week after sowing and this period was kept constant throughout the experiments. After the establishment of the seedlings, *i.e.*, in the second week after first transplantation, second transplanting was done. This period also was kept constant for the subsequent experiments. Uniform seedlings were selected for transplantation. Seedlings were pulled out securing the tops tightly and the spacing of $16'' \times 16''$ was maintained both in the control and transplanted plots throughout the experiments. There were one thousand and twenty-four plants for each treatment.

Uniform seedlings were transplanted and when established half the number were pulled out and retransplanted in the same plot similarly spaced, but the original lines were changed. After the formation of ear-heads, representative samples from the control, first and second transplantations were removed without obvious injury for studying, (i) total number of roots per plant, (ii) total root length per plant, (iii) number of laterals per inch of root, (iv) depth and spread of roots, (v) number of tillers and (vi) total shoot length. After harvest ear-heads were dried and threshed and the seed was weighed separately for every plot.

All the experiments were conducted in quadruplicate for 2 consecutive seasons (two years) to confirm the results.

Observations

Seedlings attained a height of 7 inches in the third week and they were then transplanted for the first time and they established themselves after four days. In the second week after first transplantation the seedlings were transplanted for the second time. By this time the control plants were about 12 inches in height and produced 2 tillers, and those that were first transplanted had grown to a height of 10 inches. Fifteen days after second transplantation, the seedlings had grown vigorously and were equal to the control and the first transplanted plants in height and tillering.

65-day plants, *i.e.*, one month after second transplantation, were better in general growth, height and tillering than the control and the first transplanted plants.

Tillering.—There were 6 tillers per plant on an average in control but the number increased to 18 in the first transplanted plants and it further increased to 27 in the second transplanted plants. The total shoot length also increased in the transplanted plants over the control plants; the increase being from 56 inches in the control to 170 inches in the first transplanted plant and 258 inches in the second transplanted plant.

Root System.—Control plants had about 39 roots growing to a depth of 36 inches and spreading to a distance of 20 inches. In the first transplanted plant the number of roots increased to 55 which grew to a depth of 26 inches and spread to a distance of 52 inches. In the second transplanted plants there were only 48 roots growing to a depth of 22 inches and spreading to a distance of 46 inches. The number of

laterals per inch of root was 7 in the control plant, 20 in the first transplanted plant but the number increased to 52 in the second transplanted plant. The total root length per plant in the control was 75″, 1154″ in the first transplanted plant, and 908·8″ in the second transplanted plant. The dry weight of the roots per plant also varied. It was 6·3 g. in the control, 19·05 g. in the first transplanted plant and it increased to 30·6 g. in the second transplanted plant.

There was an enormous increase in the number of roots in the first transplanted plant but number of laterals per inch of root was more in the second transplanted plant. The total root length was more in the first transplanted plant but the dry weight of roots increased in the second transplanted plant.

The usual course of the roots also changed. In the control plant most of the roots grew vertically downwards but in both the transplanted plants most of the roots grew horizontally between 4 to 8 inches below the soil surface (Table I).

TABLE I

No.	Observation/operation		Control	I Transplantation	II Transplantation
1.	Date of sowing ..	*a.*	16–11–1954	16–11–1954	16–11–1954
		b.	7– 3 1955	7– 3–1955	7– 3–1955
2.	Commencement of	*a.*	19–11–1954	19–11–1954	19–11–1954
	Germination	*b.*	11– 3–1955	11– 3–1955	11– 3–1955
3.	Completion of	*a.*	22–11–1954	22–11–1954	22–11–1954
	Germination	*b.*	13– 3–1955	13– 3–1955	13– 3 1955
4.	Date of Harvest ..	*a.*	14– 3–1955	14– 3–1955	14– 3–1955
		b.	9– 7–1955	9– 7–1955	9– 7–1955
5.	Number of tillers/ plant		6	18	27
6.	Total shoot length ..		56″	170″	258″
7.	Number of roots/ plant		39	55	48
8.	Total root length/ plant		751″	1154·9″	908·8″
9.	Dry weight of roots/ plant		6·3 g.	19·05 g.	30·6 g.
10.	Number of laterals/ inch of root ..		7	20	52
11.	Depth of roots ..		36″	26″	22″
12.	Spread of roots ..		20″	52″	46″
13.	Age of flowering:				
	a. Commencement		101 days	98 days	96 days
	b. Completion ..		120 days	118 days	113 days
14.	Yield of grain/plant		1474·2 g.	3088·2 g.	5046·3 g.
15.	Yield of straw/plot ..		18597·6 g.	24948·0 g.	30391·2 g.

The depth of root penetration decreased and spread increased in the transplanted plants over the control plants.

Flowering.—Flowering commenced first in the second transplanted plants at the age of 96 days and it was uniform. The first transplanted plants flowered two days later and the control plants flowered 5 days after the flowering of the second transplanted plants. Completition of flowering was noted first in the second transplanted plants at the age of 113 days, in the first transplanted plants at the age of 118 days and lastly in the control plants at the age of 120 days. The second transplanted plants commenced flowering earlier and completed earlier (Table I).

Yield.—The yield of grain from a plot of 1 cent in the control was 1474·2 g. and 3088·2 g. in the first transplanted plot, whereas the yield increased to 5046·3 g. in the second transplanted plot. The yield of straw was 18597·6 g. in the control plot, 24948·0 g. in the first transplanted plot and increased to 30391·2 g. in the second transplanted plot. The yield of both grain and straw increased in the second transplanted plot (Table I).

Discussion

Tiller formation increased in the transplanted plants when compared to controls, the increase being from 6 in control plant to 18 in the first transplanted and 27 in the second transplanted plant. Singh (1953) made similar observations in the chilli crop. The total shoot length also increased in the transplanted plants. In control plant it was 56 inches, in the first transplanted plant 170 inches and 258 inches in the second transplanted plant. This observation also is in complete agreement with that of Singh (1953) on chillies.

The tendency for increased tiller formation in the transplanted plants can be ascribed to the increase in root formation and there is a correlation between root output and tiller production.

Increasing root formation has been noticed when transplanted. This tendency for increase in root production can be attributed to the stimulus received due to the root injury during transplantation. Weaver and Bruner (1927) have stated that as a result of transplantation many new roots form and they do not grow to the same length as the original ones and these observations are confirmed in this investigation. Weaver and Clements (1938) on tomato and cabbage transplantation experiments observed decreased root penetration after transplantation and this is also confirmed by us. The spread of roots, however, increased in the transplanted plants over controls, the increase being 160% in the first transplanted over control.

The roots grow vertically downwards in control plant but after transplantation there is a deviation in the course of development. The roots after penetration to a depth of 4″ to 6″ on an average take a

different course and grow almost parallel to the soil surface. This indicates the possibility of growing this crop in shallow soils.

In this plant the number of branch roots (secondary) increased from 7 per inch in control to 20 in the first transplanted and 52 in the second transplanted plants. These observations lend support to the views expressed by Weaver and Bruner (1927).

Regarding flowering it can be said that the transplanted plants come to flowering earlier but Jones (1922) and Weaver and Bruner (1927) recorded otherwise.

The first transplanted plants gave 64% more yield over the control and the second transplanted gave 242% over the control. This crop is usually raised by transplantation but in some tracts it is also raised by broadcasting. It is now evident that this crop can be transplanted twice and that yield of straw and grain can also be increased. Weaver and Clements (1938) have stated that transplantation in tomato and cabbage will retard growth, delay flowering and reduce yields. Weaver and Bruner (1927) stated that when the transplanted plants were given the same spacing as those of the controls, the yield will be reduced in the transplanted plants but this is not borne out by our observations. The transplanted plants, in spite of being given the same spacing as controls, gave increased yields, more so the second transplanted plants and this is in line with Singh's (1953) observations on chillies.

The yield of straw also increased as that of grain. There is a correlation between the weight of straw and number of tillers and also a correlation between tillering and the extent of root system. In the transplanted plants the total length, dry weight and number of roots increased over the controls, similarly the number of tillers, yield of grain and straw. Weaver and Bruner (1927) observed in transplanted cabbage plants, increased root production but got reduced yields. In the present experiment there is an increase in root production correlated with higher yields.

Summary

Transplantation experiments were conducted in Ragi and the following aspects were studied: Number of roots, total root length, dry weight of roots, number of laterals per inch of root, depth and spread of roots, number of tillers, and length of shoot and yield of grain and straw.

The second transplanted plants gave increased yields. In the transplanted plants the depth of roots decreased but the spread increased. There was a correlation between root system, tillering, and yield of grain and straw. There was however, no correlation between flowering and any other factor.

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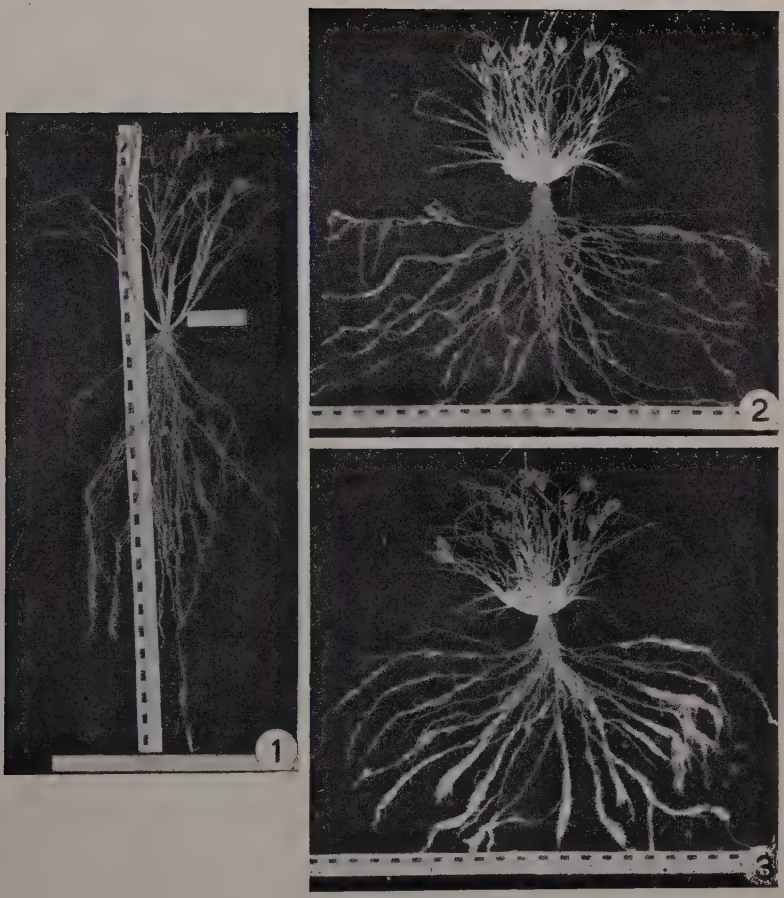

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EXPLANATION OF PLATE XVI

FIG. 1. *Eleusine coracana* Gaertn., control. Note the deeply penetrating root, system. Number of lateral roots few.

FIG. 2. *Eleusine coracana* Gaertn., I. Transplanted. Note the decrease in root depth and increase in root spread and more lateral root formation.

FIG. 3. *Eleusine coracana* Gaertn., II. Transplanted. Note the Maximum development of lateral roots and reduction in root depth.

REVIEW

Indian Manual of Plant Ecology. By R. Misra and G. S. Puri. (The English Book Depot, Poona, India), 1950. Price Rs. 15·50.

This much needed book is composed of two sections. Section "A" covers the general topic "Plants and Plant Communities". It includes 5 tables, 5 plates, 15 figures and 70 pages. Section "B" contains a discussion of "Plant Environment". Included are 105 tables, 42 figures covering 260 pages.

Section "A" is divided into three topics—Autecology, Synecology, and Methods in the Study of Plant Communities. Under autecology is found a discussion of seed output, viability of seeds, dormancy, reproductive capacity of plants, vegetative propagation, dispersal, seedling growth, vegetative growth, reproductive growth, genecology, and plant indicators.

The division on synecology considers such topics as nature and structure of the plant community, and its origin and development. Also succession is treated quite adequately under such headings as nature, process, causes and kinds of succession.

To close this division is found a description of various phases of climax, and terminology used in a classification of plant communities.

The third major division of Section "A"—a Description of Methods in the Study of Plant Communities—is introduced by a brief history of the development of methods in the study of Plant Communities, particularly in India followed by a discussion of use of the transect and quadrat in making quantitative studies of vegetation.

It is stated that while data are being collected, qualitative information also can be recorded under the headings of physiognomy, sociability, vitality, stratification, and periodicity.

Synthetic characters of a plant community such as presence, constance and fidelity are determined from the quantity and qualitative data available from quadrat studies.

The plant community is next characterized by its most dominant species and thus it is possible to make a correlation between plant communities and environmental features.

The section is concluded with a discussion of Raunkiaer's life-form system and biological spectrum.

The first seven chapters of Section "B" deal with environment of the root system and the last seven with environment of the shoot.

In the first chapter of the section consideration is given to the root system and the soil complex in general. This chapter is followed by chapters dealing more specifically with the biological system, the organic matter system, the soil solution system and soil air system.

One chapter is given to a discussion of development of soils (Pedalogy) and the closing chapter on environment of roots considers soil groups of neighbouring regions of India and the world.

The last seven chapters deal with environment of the shoot—the final subject considered in the book. Two chapters are used in a general discussion of climate, and the role of climate in the development of vegetation and soils. This general discussion is followed by a description of the climate of India.

The concluding four chapters consider in some detail, the light factor, the temperature factor, the atmospheric factor, and biotic factor.

The tables present a vast amount of data drawn from reports of workers in various parts of the world. The figures are largely maps and line drawings used to illustrate the subject under discussion. A fairly complete bibliography is included.

This book should be most useful in bringing about a clearer understanding of plant-environment relationships.

F. W. ALBERTSON,
Grassland Specialist,
K.S.C.-T.C.M., India.

RAJKOT,
January 31, 1958.

ANNOUNCEMENT

The Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal. The program will include papers and symposia related to all branches of pure and applied botany. A first circular giving information on program, accommodation, excursions, and other detail will be available early in 1958. This circular and subsequent circulars including application forms will be sent only to those who write to the Secretary-General asking to be placed on the Congress mailing list:

DR. C. FRANKTON,
Secretary-General,
IX International Botanical Congress,
Science Service Building,
Ottawa, Ontario,
Canada.

349-58 Printed at The Bangalore Press, Bangalore City, by C. Vasudeva Rao, Superintendent, and Published by Dr. T. S. Sadasivan, Business Manager, The Indian Botanical Society, University Botany Laboratory, Triplicane, Madras, 15-8-1958